INDUSTRIAL ENGINEER

Devoted to the Maintenance and Operation of Electrical and Associated Mechanical Systems in Mills and Factories

Volume 83 Chicago, April, 1925 *Number 4*

Still Running After 30 Years of Service

How These Generators Compare With Modern Standard Designs for the Same Kind of Duty

SOMETIME during 1895 the three generators shown in this photograph were installed in the Keith Theatre at Boston, Mass., and have been in service ever since. These old timers stand as silent witnesses to the sturdiness of designs of machines built 30 years ago.

The nameplates bear General Electric Company's serial numbers 1986, 1987 and 1988 with the rating indicated as MP-8-100-270, 108 volts no load and 112 volts full load. Harrisburg 150-hp., 15-in. by 14-in., single-cylinder engines, made by the W. R. Fleming Engine Company, were direct connected to them.

If these generators were to be replaced today the new ones would look quite different, by reason of the progress that has been made in design and construction to better suit operating conditions. In this particular instance the engineering department of the General Electric Company has furnished me the following statement comparing the features of modern generators for the service that these old ones have so well performed, based upon the revisions in design that have been worked out.

"Compared with the old Keith Theatre generators, the modern 100-kw., 125-volt, direct-connected generator is very much smaller and has commutating poles, with its main poles built up of laminations. The main poles are consequently, rectangular in cross-section, whereas the generators in the Keith Theatre have cast poles with cylindrical magnet cores. The following data enables a comparison to be made of certain elements as between what may be considered the original 100-kw., direct-connected generator for lighting service, and the latest General Electric standard generator."

	Keith Theatre Generator	Modern Standard Generator
Speed, r.p.m.	270	260
Number of poles	8	6
Diameter armature core overall, in.	45⅛	30
Length armature core overall, in.	12½	11
Number armature slots	136	79
Number commutator segments	272	79
Volts per segment	3.3	9.5

This information seems to indicate that today the materials in modern generating apparatus are worked harder and closer to design limits through improved construction, and through better insulation and refinements in quality of materials employed. In some cases better service is obtained than was possible with the older designs, but the greatest benefit has probably come in reduced cost per pound of machine needed for a required service. Whether this reduction in cost plus the cost of maintenance over a period 30 years from today will be less, cannot be answered conclusively until 1955, but it is a safe prediction, I think, that in 1955 we will know enough more about service requirements and both buy and use electrical apparatus with enough more intelligence and knowledge of what should be demanded in the way of efficiency to justify perhaps even closer limits of construction in 1955 than a comparison between designs of 1895 and 1925 now reveal. If anybody else has ideas along this line I have a way to make use of them and will welcome their comments.

Practical Pete

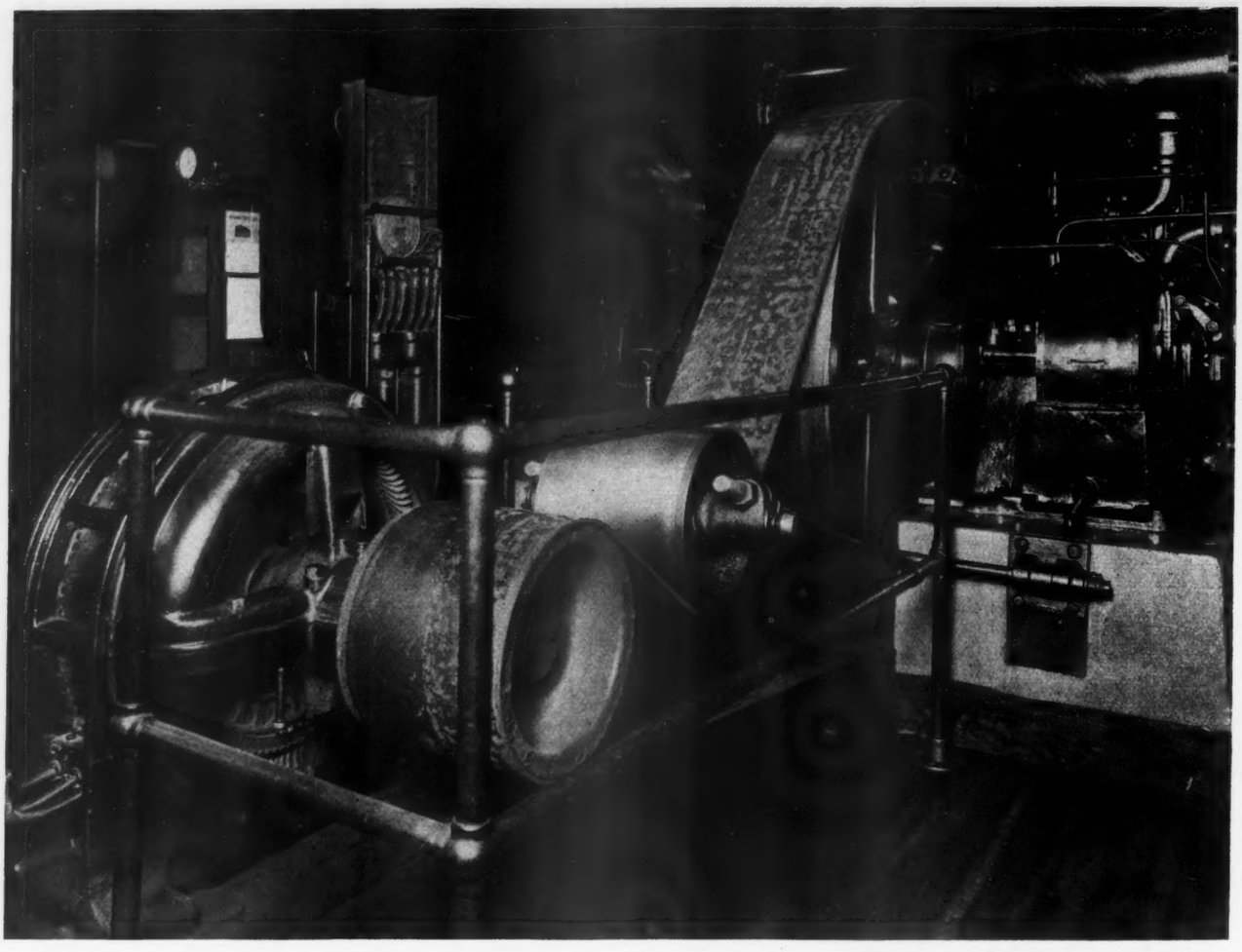

Fig. 1—Details of the arrangement of a short-center drive for an air compressor.

The idler pulley is held in position by two rods, one on each side of the idler, which are anchored to the foundation of the compressor. Half of the weight of these rods is used in computing the total idler weight. The location of the grease cup on the idler shaft can also be seen. Further details of the methods of lubricating the idler are given in Fig. 7 and on page 209. An 85-horsepower, 560-r.p.m., squirrel-cage, induction motor drives the air compressor through a 14-in. standard double-ply belt. The diameter of the motor pulley, driven pulley and idler are 18 in., 72 in. and 16 in., respectively, all pulleys having a 15¼-in. face.

What You Ought to Know About

Laying Out Short-Center Belt Drives Using Idlers

To Give Increased Arc of Contact Between Belt and Pulley, Together With Data, Tables, and Worked-Out Examples Showing How Typical Layouts Were Planned

By ROBERT W. DRAKE

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SHORT belt drives with idler pulleys are used to economize floor space in numerous applications. In many cases they are more satisfactory than gearing, and frequently offer important advantages over a direct-connected motor drive. As an example, a medium-speed, synchronous motor driving a compressor through a short belt costs less than a slow-speed, direct-connected drive, and allows the purchaser to choose a compressor large enough to take care of several years' expected growth and still gain the advantage of somewhat increased economy and greatly decreased maintenance expense in the interim by simply installing at first, an undersized motor pulley. This case is illustrated in Fig. 5. There also exists the possibility of getting the compressor back into service in case of motor trouble, by temporary use of almost any available large motor and a suitable size of pulley. If the motor available is not large enough to drive the compressor at full speed, then pulley sizes may be selected that will drive the compressor at such a speed as will fit the capacity of the motor.

Around a factory many other applications suggest themselves, such as heating fans, as shown in Fig. 3, cupola blowers of the centrifugal or

positive pressure type, plunger pumps, exhausters, and various drives where space is at a premium and the speed of the driven machine is too slow to permit direct connection, or on drives where there is a worth-while advantage in an arrangement which makes possible some changes in speed by a change in pulley sizes, as is shown in Fig. 5.

In the case of a compressor, the short-belt drive attachments, idler pulley, supporting rods, etc., are ordinarily furnished by the compressor manufacturer. For short-center drives that are built or constructed in the plant, it will be necessary for the operating man to determine the size and weight of the idler pulley and the other factors determining the character of the drive. It has been my experience that the average draftsman with considerable experience along such lines is somewhat puzzled when asked to determine the correct weight of idler for such a drive. He generally estimates the weight from that of another drive, with a liberal allowance for safety. If the man laying out the previous drive did the same thing, and in turn his predecessor, we arrive at very large factors of safety against slipping and very high resulting belt stresses.

I am outlining, in what follows, a rational method of laying out such drives. With the help of some data, which I have taken from both unsuccessful and successful drives, it is comparatively easy to plan a drive for a specific purpose, without using an unreasonably heavy idler pulley to insure against slip.

There are several factors to be considered in planning a short-center belt drive. These factors will be considered in what follows: horsepower to be transmitted, speed of drive pulley, belt speed, belt thickness, effective tension, belt width, static tension, and weight of idler.

SHORT BELT DRIVES with idler pulleys to increase the arc of contact between belt and pulley are used to save floor space, building space, and belting, as well as bearing friction, lubrication, and bearing renewals because of the reduced bearing pressure obtained thereby. The short-center drive having an idler permits the use of less expensive, high-speed, high-efficiency motors because pulley ratios that are higher than those customary with any other form of belt drive may be used with it. Determining the correct weight of idler, selecting the proper belt tension, and making proper allowance for possible overloads and other factors determining the layout for such a drive is often a puzzling matter. In this article, Mr. Drake outlines a rational method for planning such drives and with the help of several tables based on his experience, he works out a number of typical examples of short-center drives.

Calculation of Horsepower to be Transmitted by Belt

Strictly speaking, the idler weight must be proportioned to give sufficient belt friction on the driving pulley for the maximum instantaneous horsepower and not for the average horsepower to be transmitted by the belt. Thus for a belt driving a single-stage air compressor having a large variation of torque in a revolution, a heavier belt and a heavier idler will be necessary than for a fan. For a two-stage compressor, intermediate values will be indicated. Thus, in a strictly academic discussion of the problem, it would be logical to determine the maximum horsepower transmitted at any point in the revolution of the driven machine and base the layout on this value. Such a method would allow the use of the same empirical constants for all types of drives, from a severe shock load to a fan. Unfortunately, data as to the crank effort diagram of the driven machine, the effect of flywheel weight, and the motor slip, or relative drop in speed with various instantaneous loads, is seldom easily available. I have, accordingly, developed a design procedure based upon the average horsepower during a revolution with maximum load being transmitted by the drive, with a range in the empirical design constants to be applied by judgment according to the type of load, as to variability of torque during a revolution. This greatly simplifies the computations and has given satisfactory results in practice, where the variations of required driving torque are not extreme, and where the torque during the starting period does not greatly exceed the average full-load torque, as when the motor is started with one or more steps of reduced voltage by an ordinary resistance-type starter in the case of a direct-current motor, or a compensator starter in the case of an induction motor. Therefore, in the computation that follows we will use the value of horsepower required by the driven

Fig. 2—The answer to the question stated below is determined by the position of the idler pulley.

Both drives have the same size and thickness of belting and the same diameters and faces of driving and driven pulleys; in fact, both drives are the same except that in the case of the right-hand illustration the idler pulley is hung lower, thus giving a larger contact area of the belt with both pulleys. At first thought it would appear that the drive shown at the right would carry the larger load, because of the greater belt-contact area. On page 171 and in Fig. 4, the author shows that the facts are precisely the opposite.

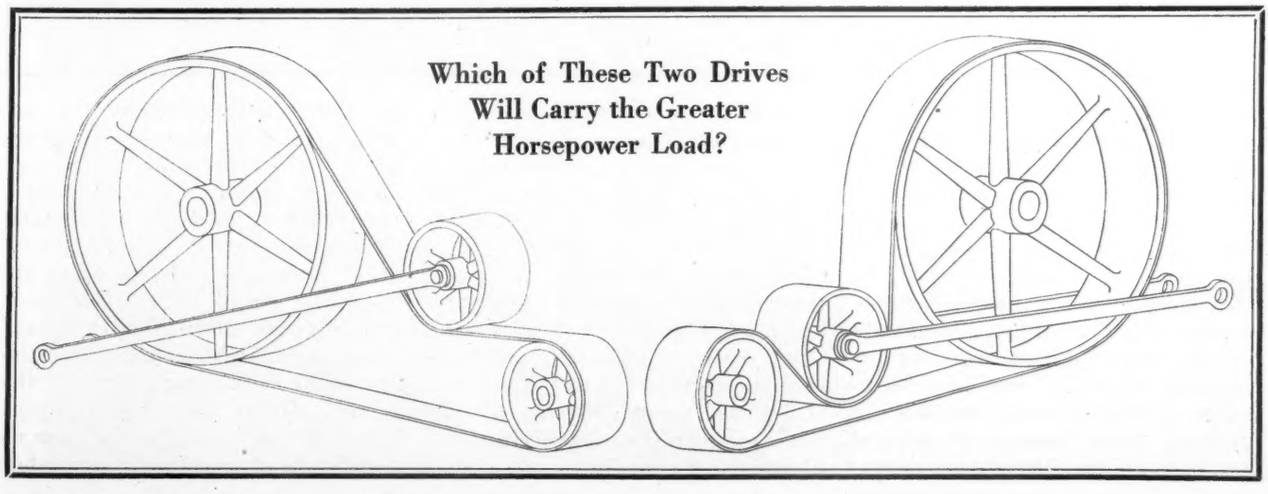


Table I—Permissible Effective Pull and Slack Side Tension for Different Belt Speeds

Belt Speed in Ft. per Min.	Permissible Effective Pull Per Inch of Belt Width for Standard Double Belt			Belt Speed in Ft. per Min.	Necessary Slack-Side Tension in Per Cent of Effective Pull		
	A	B	C		A_1	B_1	C_1
0	38.0	79.0	104.0	0	35	35	35
500	46.0	94.0	124.5	500	18	18	18
1000	47.0	97.0	128.0	1000	16	14	12
2000	45.0	96.0	129.0	2000	16	12	10
3000	40.0	91.0	123.0	3000	32	20	18
4000	32.5	84.5	116.5	4000	60	30	25
5000	23.0	75.0	107.0	5000	135	45	35

For single ply (¼-in. thick) use 50% of above values. For light double ply (⅜-in. thick) use 75% of above values. For medium double ply (⅞-in. thick) use 94% of above values. For standard double ply (½-in. thick) use 100% of above values. For three-ply (¾-in. thick) use 150% of above values.

These percentages apply to belts of any thickness. The percentages in column A_1 apply to the data in column A; those in column B_1 to column B; and those in column C_1 to Column C.

(1) This table is correct for short belt drives with idlers, where the motor pulley is made of paper and the drive is so laid out that the arc of contact with the motor pulley is from 210 to 230 deg. when the belt has stretched so that the upper belt almost touches the lower belt. This table is not intended for use with lineshaft drives without idlers, nor with the idlers unless the smaller pulley is paper.

(2) Column *A* is based on a total tension on the pull-side of 54 lb. per in. width of double-ply belt running at a speed of 4,000 ft. per min., with slightly different values at other speeds as recommended by Barth. With excellent maintenance based on F. W. Taylor's experiments at Midvale, this should give a belt life in 24-hr. service of 18 yr. Few belts get such excellent care. Use data from this column for drives in 24-hr. service, or important drives in 10- or 12-hr. service where a delay from belt trouble once in a year or two would be serious or troublesome and where the additional first cost is warranted to avoid it.

(3) Column *B* is based on a total tension on the pull-side of 111 lb. per in. width of standard double-ply belt running at a speed of 4,000 ft. per min., with slightly higher tensions at lower speeds and slightly lower tensions at higher speeds, approximately according to Barth's recommendations. According to Taylor's experiments, belts run 24 hr. per day with about this total tension will last seven years if given exceptional maintenance. The data in this column are suitable for the design of drives carrying a very constant load (no fluctuations) where the equipment is operated only a few hours per day or only a few months per year, for example, heating fans. These data are also suitable for the layout of drives carrying a constant, or nearly constant load, such as ventilating fans, where operation is for 10 or 12 hr. or more per day, and where a case of belt trouble occasionally will not interfere with production.

(4) For drives where the torque is fairly uniform, as on compressors with flywheels, Root or Connelsville blowers, and the like, use effective pulls between the values in columns *A* and *B*, using values nearer those in column *A* for 24-hr. service, for more important drives, and for drives where the torque is more variable (as on single-stage compressors); and values nearer column *B* for 10-hr. service on less important drives and for drives where the torque is less variable, such as on two-stage compressors.

(5) Column *B* is also suitable for checking or planning a drive for starting conditions or high swings with extremely variable load where this is likely to be the limiting feature of the design, and the most extreme reliability is essential, or where the service is exceptionally severe as in the frequent starting of a squirrel-cage induction motor in a location where there is dust which will decrease the friction of the belt on the pulley, and where the belt will not be well cared for.

(6) Column *C* is based on a total tension on the pull side of 146 lb. per in. of width of standard double-ply belt at 4,000 ft. per min. with slight variation for higher and lower speeds. This was about the stress which was considered advisable by old-time millwrights. Engineers of late years have been using lower stresses because of the greatly increased belt life, greater reliability, and lower maintenance. I do not recommend the use of such stresses for steady running in any design, even for occasional use. However, it is reasonable to use such stresses during the starting period on drives where more torque is exerted during starting than during running (such as cases where small induction motors are started "across the line" without a compensator) and where such stresses do not occur too frequently.

(7) On drives where the maximum torque of the motor is two or two and one-half times the nameplate rating, and the nature of the load is such that this torque or something approaching it may be expected to be exerted occasionally (for example, a jaw crusher for rock) it is necessary to check the design for maximum torque. If the drive is unimportant and occasional belt trouble not of serious importance, the values in column *C* are reasonable for this purpose. If reliability is of more importance or conditions are unfavorable to the belt, such as dust, out-of-the-way location where poor maintenance may be expected, and the like, it is often advisable to use values somewhere between those of columns *B* and *C* for checking maximum torque. Only where the maximum torque of the motor is exerted frequently and extreme ruggedness and reliability are desired is it necessary to keep the stresses as low as those of column *B* at the stalling point of the motor.

(8) Use the percentages in columns A_1 B_1 and C_1 in determining the slack-side belt tension for loads having a variation in torque no greater than that of a two-stage compressor or a Root blower.

(9) For loads having a variation of torque in each revolution, like a single-stage compressor with a flywheel, multiply the above percentages by 1.15.

(10) For loads having greater variation in torque than a single-stage compressor with flywheel, such as any mechanism having a crank and *no* flywheel, compute or estimate the maximum torque during the revolution and figure both effective pull and per cent static tension on that basis. In such a case use the above percentages unaltered.

(11) The percentages in columns A_1, B_1 and C_1 apply to drives where the angle of contact between the belt and driving pulley is 210 to 230 deg. when the idler pulley is at its lowest position. Most such designs as we are considering fall within this range. In case special conditions make it advisable to lay out a drive where the angle of contact falls outside this range, correct the above table by multiplying the tabular percentages by constants as follows:

Angle of "Wrap"	Multiplying Constant
180 deg.	1.12
190 deg.	1.09
200 deg.	1.06
240 deg.	0.965
250 deg.	0.95

machine for the maximum continuous load that will ever be carried for any length of time. If the driven machine will be overloaded for several minutes, this load must be used.

There are certain drives which have not lent themselves readily to this method of treatment, such as drives where a torque occasionally occurs either during starting or running, which is very large compared to the average torque. In general, these occasional extreme torques are the limiting conditions in such drives, and the drives must be planned to meet them, both as to the size and strength of the belt required and as to the weight of idler necessary to prevent the belt from slipping. Such drives are:

(*a*) Machines driven by small squirrel-cage, induction motors which are started directly across the line. Such motors ordinarily develop at starting 125 to 150 per cent of full-load torque, which gradually increases with increase of speed until at roughly 75 per cent of full speed they develop 200 to 250 per cent of full-load torque (not horsepower). The lower value is for slow-speed motors, say up to eight poles and the larger value is for four- and six-pole motors.

(*b*) Some machines in severe applications, such as coal or rock crushers, not infrequently sustain momentary loads approaching the maximum or stalling torque of the motor. Often the shearing pins break at this load. In the case of some kinds of machines, a horseshoe

or some freight-car part comes through in the raw material just often enough so that it is impracticable to burn up a belt every time this happens.

My method of designing such drives is to so proportion the belt and idler pulley, that the drive will carry the maximum torque or stalling torque of the motor without injury to the belt through over-stress or slipping of the pulley.

If these extreme stresses are infrequent, it is unnecessary to maintain as low belt stresses through their duration as would be reasonable for continuous operation. Suggestions for suitable stresses to allow during these extreme overloads will be found in the notes following Table I.

Generally, it is necessary to figure such a design through for average running conditions and again for starting or extreme overload conditions. The weight of the idler pulley required is almost invariably determined by the starting or overload conditions. The size of belt required is sometimes determined by the overload or starting condition and sometimes by the normal load condition. This seeming anomaly is due to two facts.

(*a*) The design for the occasional heavy load during starting or overload is figured on a basis of heavier belt stresses than is the normal running load.

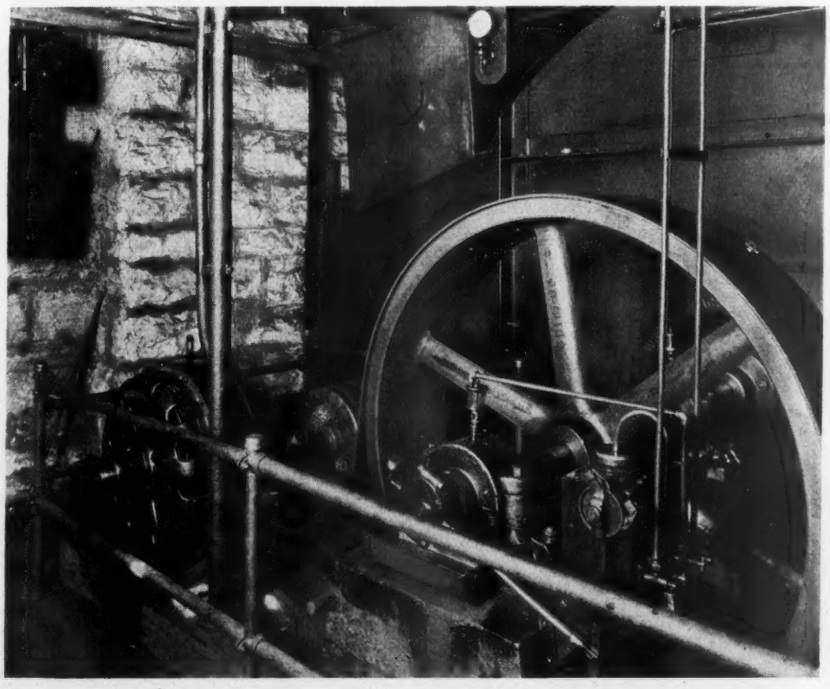
(*b*) The extreme load or stalling torque occurs at approximately 75 per cent of normal speed. If the drive is so planned that the belt speed is close to 5,000 ft. per min. at normal running speed, the belt will be working under much more favorable conditions as to grip on the pulley at 75 per cent of that speed (see Table No. I).

When the weight of idler pulley necessary to carry the occasional heavy torque in a drive of this kind greatly exceeds the weight of pulley necessary for normal running and the design for normal running happens to determine the size of belt, it is well to increase the belt width slightly to allow for the increased weight of idler pulley over that corresponding to the assumptions on which Table I was calculated. Particularly is this true when normal running stresses are assumed higher than those shown in column *A*, Table I.

A direct-current, compound motor or even a shunt motor is capable of exerting a torque far greater than 200 to 250 per cent of full-load torque. Such motors are seldom started across the line, except in extremely small sizes, but they are sometimes used on drives where they develop extremely high, momentary torques. In designing a short-belt drive for such an application, I know of no rational procedure except to determine by some means the maximum torque to be expected.

Fig. 3—This motor and short-center belt drive have replaced the steam engine formerly used.

The flywheel on the steam engine was used for the driven pulley and the short-center drive shown just fits into the space formerly occupied by the engine. A 75-hp., two-speed, 600-1200-r.p.m., squirrel-cage, induction motor is used, which drives the heating and ventilating fan through a 12-in. belt. A 12-in. diameter pulley is used while the diameter of the driven pulley is 60 in. and the diameter of the idler is 16 in. The pulley faces are 13 in. wide.



Effect of Drive Pulley Speed and Belt Velocity

The drive pulley speed is generally fixed by the speed of the motor to be used. If an attempt is made to design a drive for a motor having too high a speed, it will figure out unreasonable in proportions and the necessity for a change in motor speed will be evident.

Within certain limits, as the speed of the belt is increased, the width of the belt may be decreased. This causes less load on the motor bearings, which gives longer life and cooler running. Increasing the belt speed and at the same time keeping the shaft or pulley r.p.m. the same, means increasing the pulley diameter which results in the belt being bent less sharply over the pulleys, thereby giving a longer belt life. Carried to an extreme, this results in belt speeds such that the belt tends to leave the pulley by centrifugal force and the actual power transmitted by friction is greatly reduced. Translating this into definite figures means that up to a maximum of 4,000 to 4,500 ft. per min. belt speed, the higher the belt speed, the better and cheaper will be the design; from 4,500 to 5,000 ft. per min. there is no worth-while gain unless starting conditions are rather severe; beyond 5,000 ft. per min., the drive is definitely poorer and more expensive.

Then let us say, make the speed as near to 4,000 to 4,500 ft. per min. as other conditions will allow. Generally this speed is limited by the largest pulley which can be put on the driven machine without striking the floor or the ceiling, by the size of flywheel furnished as standard by the manufacturer (as on a compressor), where a change would be too expensive to consider; or by some other similar consideration.

Considerations Affecting the Belt Thickness

In some cases the question may arise in the designer's mind whether to use single- or double-ply belt, or whether to use double- or triple-ply belt. In this connection, F. W. Tay-

Table II—Analysis of Six Examples of Short-Center Belt Drives

Hp. Load by Test	Motor R.P.M.	Belt					Pulley Diameter	Weight of Idler, Shaft, and ¼ of Rods	Weight of Idler, etc., per Inch Belt Width	Idler at Lowest Position			Idler Lifted ½ Pulley Diameter			Nature of Load	Remarks
		Width	Thickness	Effective Pull per Inch of Width	Velocity of Belt Ft. per Min.	Type of Belt Splice				Static Idler Tension per In. of Belt Width	Arc of Belt Contact in Degrees	Static Tension in Per Cent of Effective Pull	Static Idler Tension per In. of Belt Width	Arc of Belt Contact in Degrees	Static Tension in Per Cent of Effective Pull		
70	580	15	Dble.	62.5	2580	Cemented	17.0	287	19.0	10.0	236	16.0	15.5	206	25.0	Two-stage compressor	Entirely successful
70	580	15	Dble.	62.5	2580	Cemented	17.0	192	12.8	6.67	236	10.7	10.4	206	16.7	Two-stage compressor	Slipped every time splice passed pulley
44	1150	12	Dble.	40.0	3610	Cemented	12.0	183	15.2	8.3	230	21.0	12.0	210	30.0	Fan	No slip whatever. Belt doesn't touch drive pulley at edges. Contact width 7 to 8 in. instead of 12 in.
160	600	28	Dble.	66.7	2830	Cemented	18.0	880	31.5	18.2	208	27.0	20.5	204	31.0	Two-stage compressor	Successful. Slip not apparent but smell leather frequently. Measured slip, 1.4%, which is normal.
11	1150	4	Single	24.0	3600	Cemented	12.0	41	10.3	....	225	....	....	....	....	Vent. Fan	Entirely successful if motor is started with compensator.
	580	18	Dble.	47.0	2330	Cemented	15.5	....	....	....	229	....	....	....	....	Root Blower	Motor starts against heavy inertia load. No apparent slip at start or running.

lor, as a result of his classical experiments at Midvale, continuing through nine years, recommended as follows:

(*a*) Belts are more durable and more satisfactory when made narrow and thick rather than wide and thin.

(*b*) It is safe and advisable to use a double-ply belt on a pulley 12 in. in diameter or larger; a triple-ply belt on a pulley 20 in. in diameter or larger; and a quadruple-ply belt on a pulley 30 in. in diameter or larger.

These recommendations were based mostly on drives without idler pulleys. Where idler pulleys were used, they were not close to the driving pulley, as in the class of drives which we are considering, but several feet distant. Therefore, the sharp reverse bend around the idler pulley, which is characteristic of our drives, was absent. It is likely, therefore, that it will be best when possible, to modify Taylor's recommendations to the following:

Do not use double-ply belts on pulleys smaller than 14 in. in diameter.

Do not use three-ply belts on pulleys smaller than 24 in. in diameter.

Do not use four-ply belts on pulleys smaller than 36 in. in diameter.

Where the special exigencies of the design demand it, it is perfectly practicable to use the smaller pulleys in Taylor's recommended list and "get away with it."

Selection of Effective Belt Tension

In the middle of page 167 we spoke of the variation of the torque in a revolution, required by some drives. This torque variation causes a variation in the tension on the belt. In our calculations for the drive we will use an average value of belt tension which we will call the effective belt tension. These values, which are given in Table I, have been determined from my experience.

Most pulleys are made nowadays of paper. The constants and discussion here given assume that paper motor pulleys will be used. With iron or wood pulleys larger belts are necessary.

For short-center belt drives you can work the belt somewhat harder than on an ordinary drive for the ratio of the slack-side tension to the pull-side tension is far lower than with direct drive. The total tension on the pull-side is correspondingly reduced. This is partly due to the large arc of contact on the small pulley, partly to the fact that the slack-side tension is fixed by the designer and no overstressing is necessary to allow for subsequent slacking off as the belt stretches, and partly to the fact that the small driving pulley is paper. Our experimental results check this conclusively. The best known data on belt stresses

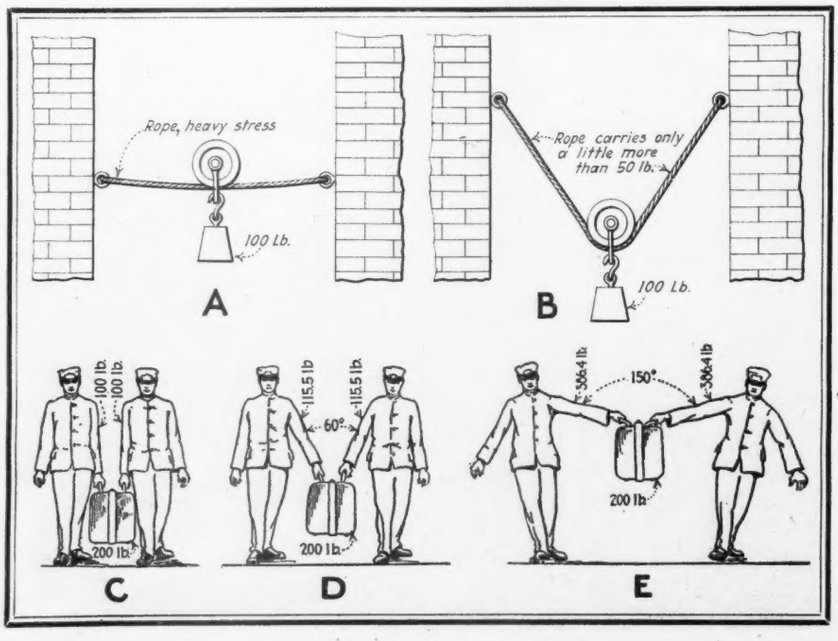


Fig. 4—Is the rope shown at A under greater stress than the one shown at B?

The answer is yes and is borne out by the two men carrying a heavy traveling bag, as shown at *C*, *D* and *E*. At *C* the men stand close together with their arms hanging straight down and parallel so that each carries half the weight of the bag, or 100 lb. At *D*, they are standing farther apart, which means they must pull a little as well as lift, with the result that there is a tension on their arms of 115.5 lb. At *E*, it can easily be seen that they must exert quite an effort in lifting the bag. Diagrams *A* and *B* are analogous to the left-hand and right-hand diagrams, respectively, of Fig. 2.

are probably F. W. Taylor's* published values based on his experiments at Midvale. Many engineers know how their practice in ordinary belt drives compares with his recommendations. For this reason in the notes following the tables, I give some reference to the two types of belt drive designs discussed by him, that is, to layouts in which the maximum stress in the belt is limited to 54 lb. per in. width of double belt as he recommended, and layouts in which stresses of about double that value are permitted.

Methods of Finding Belt Width and Static Tension

Having selected from the data in Table I an appropriate value for the effective tension per inch of belt width, compute the belt width according to the following formula:

Width in inches equals (horsepower×33,000)÷(belt speed×effective tension per in. of belt width).

With the motor and driven machine stationary, there is a tension on the belt due to the weight of the idler pulley. If there were no friction in the bearings, this tension would be equal in all parts of the belt when the machine is not running. For want of a better name, we will call this the static tension. A certain minimum static tension is necessary to produce the necessary friction between the belt and the driving pulley. Once we determine this necessary static tension, we are in position to determine the weight of the idler pulley required to produce it.

*Transactions of the American Society of Mechanical Engineers, Volume 15.

Table III—Relation of Contact Arc to Loading

With a given net tension (static tension less tension due to centrifugal force) in the belt on the slack side of the pulley, a drive will carry the following relative loads with variation in proportion of pulley surface in contact with belt.

Arc of Contact in Deg.	Relative Loads	Arc of Contact in Deg.	Relative Loads
150	0.85	200	1.06
160	0.90	210	1.09
170	0.95	220	1.12
180	1.00	230	1.14
190	1.03	240	1.16

The study of the design data and operating results of six drives in service (see Table II) indicates that a convenient method of estimating this static tension, is by the use of a percentage of the average effective tension.

The conditions as to arc of contact, angle of supporting rods and necessary static tension are not constant for any one drive. As the belt stretches the idler takes a lower position, the arc of contact increases, and due to the change in the angles of the belt on the slack side, the static tension decreases. When the upper belt almost touches the lower, the operator moves the motor away from the driven machine, which raises the idler, and the process starts over again.

It would appear at first thought that a drive would carry more load when the idler is low, as shown at the right of Fig. 2, than when the idler is high, as shown at the left of Fig. 2. The contact area of the belt on the pulley is greater in the former position. Almost any millwright or operating man takes this view of the matter. If he has trouble, he adjusts the motor on its base to obtain greater wrap of the belt on the driver pulley. The facts are precisely the opposite.

The maximum load which the drive will carry without excessive belt slip depends somewhat upon the arc of contact, but not in proportion to that arc. The exact relationship is shown in Table III. This shows that for arcs above 180 deg. the gain is not great. The maximum load depends also upon the static tension or stress on the slack side of the belt, and (belt velocity remaining unchanged) is directly proportional thereto. It is this loose-side tension which keeps the belt in contact with the driving pulley, and produces the driving friction. Now, once the weight of the idler pulley is fixed, this loose-side tension depends upon the position of the idler. The conditions are exactly analogous to those shown in Fig. 4. It is evident that the stress in the rope will be enormously greater at *A* than at *B*. This effect is so much more marked that it entirely offsets the disadvantage of less arc of belt contact on the driving pulley in the case at the left of Fig. 2 and further greatly increases the maximum horsepower load possible for the drive to carry. However, the fact remains that the millwright or the operating engineer almost invariably

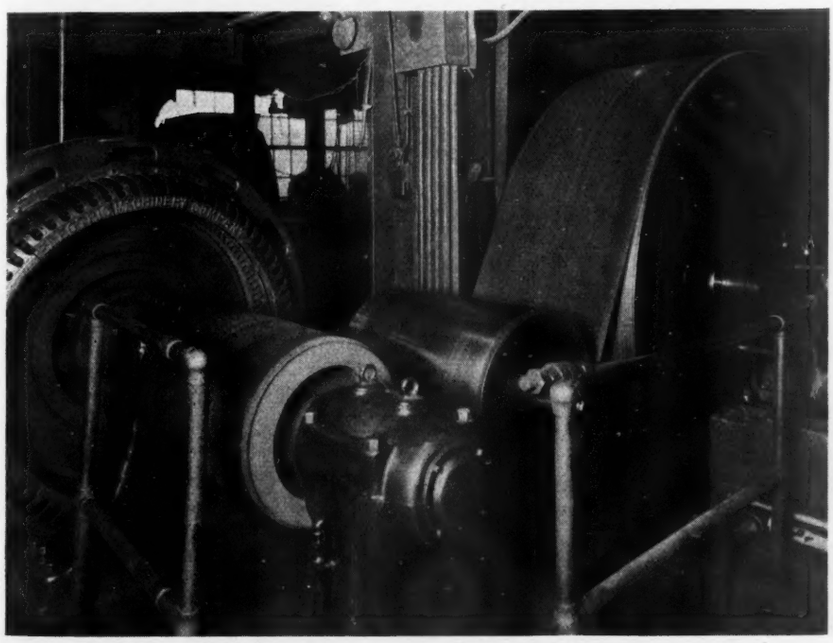


Fig. 5—The small space available made a short-center drive imperative at this location.

This drive is located in a basement, one wall of which is just to the left of the motor (cannot be seen in illustration) and the other wall is immediately to the rear of the air compressor. This air compressor is driven by a 450-hp., 600-r.p.m., synchronous motor through a 28-in. standard double-ply belt running over a 16-in. motor pulley and an 84-in. air compressor pulley. The idler is 22 in. in diameter. All of these pulleys have a 29-in. face. As can be seen this drive is coupled very closely together. With the arrangement as now used, the air compressor runs close to 120 r.p.m. with the 450-hp. motor developing about half of its normal rating. When the requirements for air become heavier a larger pulley will be placed on the motor, thus speeding up the air compressor so as to meet the new requirements. Since the efficiency of the synchronous motor is only about 2 per cent lower at half-load than at full-load, this arrangement of motor drive makes a very desirable combination, giving high economy and low maintenance for present requirements and yet having sufficient capacity to take care of anticipated future growth.

fails to see it that way, and even if instructed by a card or booklet shipped with a purchased machine, or by word of mouth, his successor will not be benefited. Every drive should be designed so that it will operate entirely satisfactorily in such a position as that shown at the right in Fig. 2. If through error, or failure to appraise correctly the degree of non-uniformity of torque, the designer fails to proportion the weight of the idler pulley correctly, it is often possible to operate the drive satisfactorily by shortening the belt. In such a case it is best to arrange a stop to make it impossible for the idler to take a low position, or to supply a heavier idler pulley when convenient. Otherwise, trouble and dissatisfaction are sure to follow.

Before the above digression we had progressed to the point of determining the static tension. We had decided that as convenient a basis as any for tabulating the results of experience for use in future designs was to express this quantity as a percentage of the average effective tension. Then during our digression we decided that it was advisable to proportion all designs on the assumption that they would sometimes be called upon to operate in the position shown at the right in Fig. 2. Based on the above premises and an analysis of the six drives ranging from 5 hp. to 200 hp. given in Table II, reasonable assumptions for the static tension expressed as a percentage of the average effective tension are given in columns A_1, B_1 and C_1 of Table I. The data for a belt speed of 5,000 ft. per minute, which lies somewhat beyond any of our experimental values, were determined by computing the effect of centrifugal force, by the method of analysis published by Carl Barth** with modifications of the constants for the difference in assumed conditions. Since no experimental data at this speed on a drive of the type which we are discussing were available, a larger factor of safety was introduced into these data; that is, the data at 5,000 ft. are presumably safer than the remaining data in Table I.

How the Required Idler Weight for an Installation Is Found

So far, we have determined our effective tension and from it, by the selection of an appropriate percentage from Table I, our static tension. The last step is to determine the necessary weight of idler, including therein that part of the weight of the supporting rods and fittings, which is borne by the idler. Let us call this total the effective weight on the idler. The best method for obtaining this weight is by a simple layout.

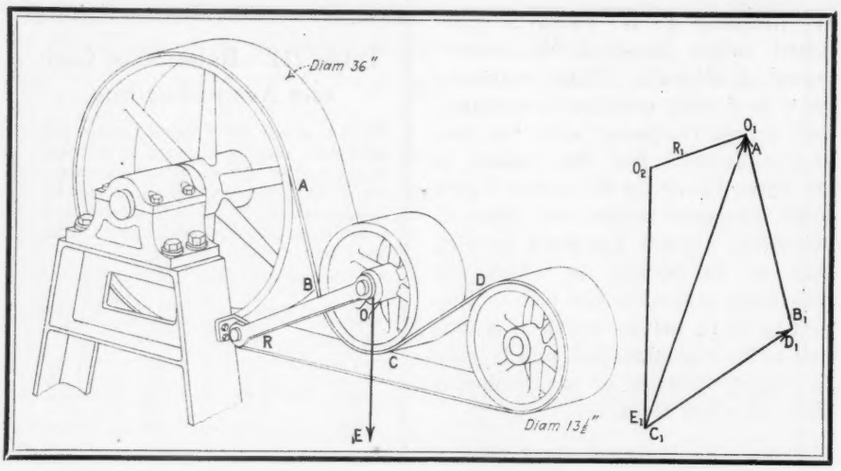


Fig. 6—Method of determining the weight of idler required for a short-center belt drive.

The tension in the belt between C and D is laid off graphically at C_1D_1 parallel to CD. The same is done at A_1B_1 for the belt AB. We now lay off O_1R_1 parallel to the hinge rod OR and also O_2E_1 parallel to OE, which represents the weight of the idler. Now measure O_2E_1 from its intersection with O_1R_1 to E_1. This distance measured by the same scale used in laying out A_1B_1 and C_1D_1 gives the idler weight.

Anyone who is at all familiar with graphic statics as applied to the determination of stresses in structures will immediately recognize the principles involved. However, do not permit a lack of familiarity with this subject to deter you. The layout is so simple that it makes little difference whether you understand the principles or not. First make a scale layout of the proposed drive *with the idler in the position which it will take when the belt has stretched until the upper belt almost touches the lower.*

The stresses in the belt AB and CD of Fig. 6 are equal; they are the static tension determined as described above. Lay out C_1D_1 to some convenient scale, parallel to CD and numerically equal to the static tension. Lay off A_1B_1 parallel to AB and *equal to* C_1D_1. OE represents the required effective weight of the pulley and is of course perpendicular to the floor. RO is the hinge rod which supports the idler pulley. Lay off O_1R_1 parallel to OR and draw O_2E_1 parallel to OE. Measure O_2E_1 from intersection to intersection. The length will give the effective weight of idler required, to the same scale assumed in laying off C_1D_1 and A_1B_1.

From this effective weight we must subtract that part of the weight of the two hinge rods and fittings which are supported by the idler. Since these weights amount to a comparatively small part of the total weight of the idler pulley, it will be sufficiently accurate if we deduct from the effective weight of the idler as follows: (1) The weight of the shaft and fittings which clamp it to the hinge rods. (2) Half the weight of the two hinge rods. The result is the net weight of the idler pulley needed.

Example of Computations for an Air Compressor Drive

Let us lay out the drive arrangement for a single-stage air compressor driven by a direct-current motor running at 1,150 r.p.m. The motor starter is of the ordinary manually-operated, resistance type. Rated speed for the compressor is 425 r.p.m. The compressor pulley is 3 ft. in diameter. The manufacturer's bulletin states that 7.2 hp. is required to drive the compressor under our conditions of volume and pressure. The layout for the drive is shown in Fig. 6.

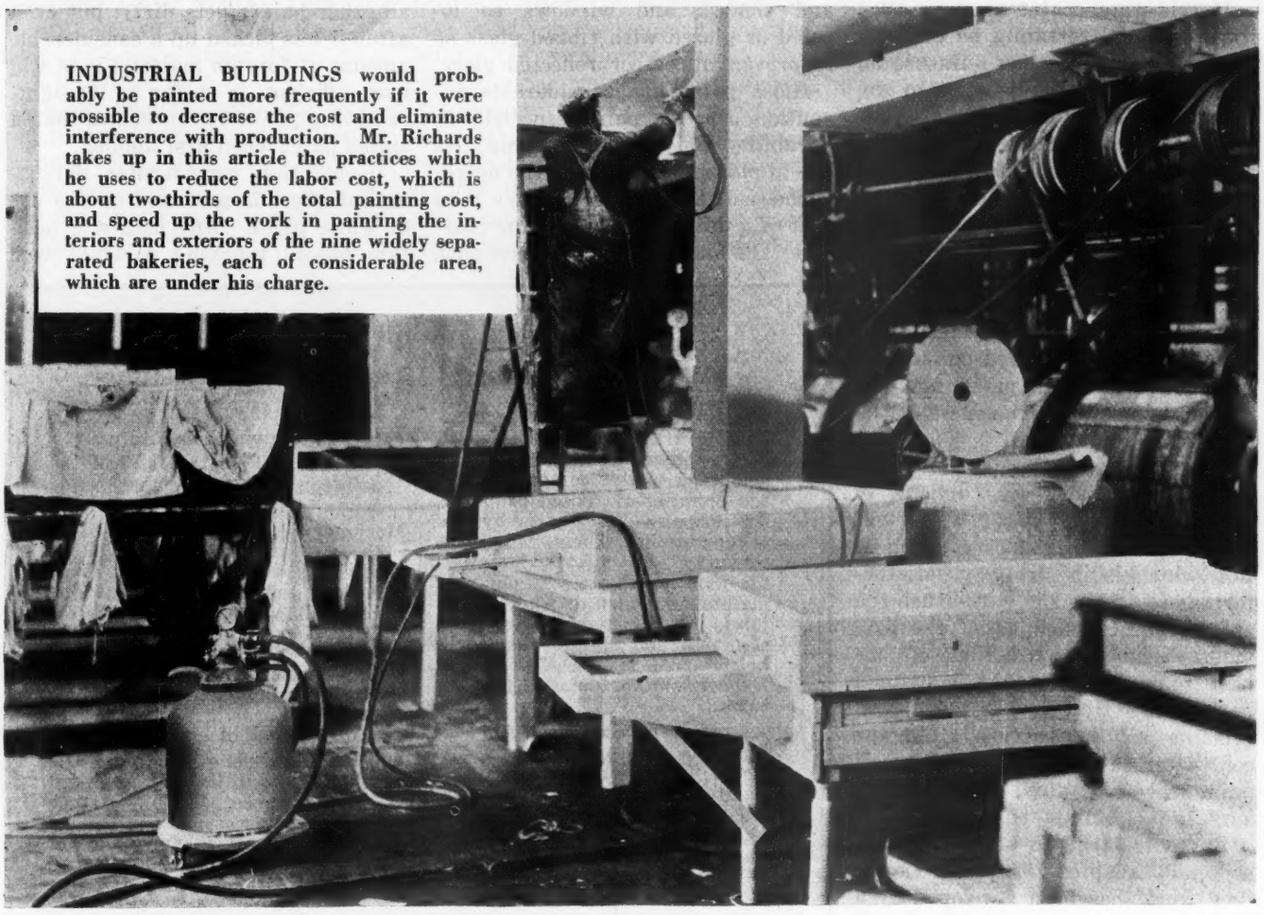
We cannot very well change the compressor pulley; so our belt speed is fixed in spite of us. It is equal to the compressor r.p.m.×diameter (in feet) of compressor pulley×3.1416=425×3×3.1416=4,010 ft. per min. Since our motor runs at 1,150 r.p.m., in order to secure the correct compressor speed the motor pulley diameter must equal [diameter (in inches) of compressor pulley×compressor r.p.m.÷motor r.p.m.]=(36×425) ÷ 1,150 = 13.3 in. Since there may be some slip or creep in the belt we will use a pulley diameter of 13½ in.

An effective tension of 50 to 60 lb. per in. of standard double-ply belt is suitable for our design (see Table I and notes 2 and 3).

Reference to columns A and B of Table I will show that the effective pull

(*Please turn to page 207*)

**Transactions of the American Society of Mechanical Engineers, Volume 31.



INDUSTRIAL BUILDINGS would probably be painted more frequently if it were possible to decrease the cost and eliminate interference with production. Mr. Richards takes up in this article the practices which he uses to reduce the labor cost, which is about two-thirds of the total painting cost, and speed up the work in painting the interiors and exteriors of the nine widely separated bakeries, each of considerable area, which are under his charge.

In working around machinery, a stepladder is sometimes the most advantageous type of scaffolding. In cases such as this, it is well to have a helper or two to arrange drop cloths ahead of the painter and remove them after he has passed.

Practical Points to Consider in

Mechanical Painting of Industrial Plants

With a Discussion of the Application and Advantages of Such Painting Together with Specifications for Various Types of Industrial Jobs

By KEENE RICHARDS
Industrial Engineer, Grennan Bakeries, Inc., Detroit, Mich.

CONSERVATION of daylight, particularly during the winter, and the maximum utilization of artificial light emphasize the importance of the proper maintenance of interior painting in factories and shops.

Several different classes of materials, for example whitewash, cold-water paints and oil paints, are available for use in painting the interiors of industrial plant buildings and inasmuch as the selection of the proper material is a matter of considerable importance it will be worth while to consider briefly the advantages and disadvantages of each. First, however, I want to call attention to a fact that is sometimes overlooked: The labor required to apply the paint, the interference with production, and the cost of preparation of the surface are the greatest factors in painting. The cost of the material is approximately only a third of the total cost. Obviously, the cost of the labor and the interference with production are the same whether whitewash, cold-water paints or oil paints are applied. For this reason it would be unwise to use any but the best material as any saving in materials would be overbalanced by more frequent paintings or difficulties incidental to this application.

As a general proposition, the use of cold-water paint or whitewash is not to be recommended. The cost of preparing the surface after the first few coats is much greater when cold-water paint is used; in fact this is its greatest fault, and it is so serious that its use should never be considered except for buildings of the most temporary character.

The writer has found from experience that it is practically impossible to prevent cold-water paint from flaking off. If used on new work it does not penetrate and secure a proper bond; if on old work it flakes continually taking not only the new coats, but some of the old material and often coming off clear down to the original surface.

If cold-water paint must be used its use should certainly be confined to plaster and masonry. Its use on ceilings is out of the question in any plant handling food or any other material in which the presence of flakes of paint would be objectionable, as any building vibration will be accompanied by a shower of paint flakes of various sizes. Another bad feature is the fact that this difficulty will not show up until the structure has been in use for some time after painting. For this reason several coats of cold-water paint may be applied before the seriousness of the damage is appreciated.

After cold-water paint has once been applied, it is very difficult to apply any covering over it which will stick. The only manner of application which is in any way satisfactory, is to scrape and wire-brush the entire surface until all of the previous coating that will come off has been removed. Oil paint may then be applied. However, if much lime remains on the surface from the cold-water paint, several coats of oil paint will be required before a good surface is secured.

A particular type of white paint especially adapted for use in industrial work, has been developed by a number of concerns. The best type of this paint, I believe, is that with a gloss surface as it catches and retains dirt to a less extent than some other types. A liberal use of paint of this sort will produce wonderful results not only in the appearance of the building but in actual saving of artificial light. Even though white paint shows dirt readily, it is by far the best surface coating for the upper parts of walls and for ceilings.

Various arguments are advanced in favor of the use of cream color, slightly buff or other tinted paints. In my opinion their use is not to be recommended. If the original color could be maintained free from dirt, there might be some advantage in having the paint toned down with some light tint. These paints, however, soon become uniformly dead in color and produce a gloomy appearance with practically no conservation of light. Objection is sometimes made to white paint, particularly of gloss variety, in that it is said to cause glare. The glare is produced primarily by poor or improperly located sources of light. The primary object of the paint on the walls and ceilings of industrial buildings is to reflect all light available. Electric light bulbs should be properly located and shaded, and windows so located or glazed with ribbed glass as to prevent direct or reflected glare.

Gloss paint has considerable advantage over flat paint, especially in durability and ease of cleaning. Its life in place is probably in the neighborhood of 20 per cent greater than that of a flat paint of the same character. White paint in common with all other paints gets dirty, but even after it has picked up a considerable amount of foreign material it is still more efficient, in so far as its light-reflecting power is concerned, than a tinted paint when first applied.

In addition considerable psychological effect is produced by the use of white paint. Any man will hesitate before touching a white wall

Standard Specifications for Industrial Painting at Grennan Bakeries, Inc.

General—The following specifications will be strictly adhered to in the painting of all buildings belonging to this company, or in the painting of rented property, the cost of which is borne by this organization. These specifications will be enforced whether the painting is done by our own maintenance men or whether the job is let on contract. New construction and special cases will be referred to the *Engineering Department* for detailed instructions.

Preparation of Surfaces—All surfaces to be painted must be clean, free from grease, loose paint and rust. It is an absolute waste of time and material to paint over an improperly-prepared surface. New work must be properly prepared by shellacking all knots or creosote stains and in the case of exterior work, by proper priming.

Walls and Ceilings—Rice's Barreled Sunlight (U. S. Gutta Percha Paint Co., Providence, R. I.) will be applied to walls and ceilings. This material will be sprayed on in every case when under contract and on maintenance work in our plants which have the necessary equipment. In the smaller plants or for smaller jobs, it may be brushed on.

Dado—A 4-ft. dado with a 2-in. black strip at the top will be applied after white is thoroughly dry. The white will be carried under the dado only on new work. This dado will be of Lucas brown dado color made by John Lucas Co., Philadelphia, Pa.

Radiators—Radiators will be painted with the same materials as the dado with the exception of ceiling radiators which will be painted white.

Metal Windows—Metal windows will be primed with red-lead primer and one coat of black enamel. Wooden window frames on the interior will receive the same treatment as the adjacent wall surfaces.

Piping—All pipe and conduit, with the exception of the sprinkler system, will be painted the same as the adjacent surface. Sprinkler system will be painted with one coat of red-lead primer and one coat of Lucas vermilion piping enamel. Boiler fronts, water heaters and exposed tanks will be painted with graphite paint.

Fire Doors—Fire doors will be painted with Lucas grey dado color.

Machinery—(a) Machines used in the preparation of our bakery products are painted with Valentine's enamel primer and one coat of Valspar (Valentine & Co., New York City) white enamel. (b) Ammonia compressors, pumps and other miscellaneous equipment receive one coat of Lucas grey dado color and one coat of clear varnish.

Office Walls and Ceilings—Old calcimine will be removed in every instance. Walls will then be sized if necessary and treated with light-buff calcimine, either Alabastine or material of equal quality. Dado will be Lucas brown dado color with 2-in. black strip at the top. Woodwork will be egg-shell varnish; radiators are to match adjacent surface.

Exterior—All new surfaces will be properly prepared and primed; in the case of metal, with red lead; in the case of wood, with white lead and linseed oil. After the priming coat the succeeding coats will consist of two parts of white lead, one part zinc oxide, mixed with linseed oil and not to exceed 10 per cent turpentine. This mixture will then be tinted to the color selected. Fire escapes, metal windows and exterior metal work, which are not to be the same color as the body of the building or trim, will be finished with graphite paint.

Workmanship—No work is to be done on damp surfaces, nor is any exterior work to be done on rainy days or when the surface is in unsuitable condition. The spray method will be used wherever possible as labor ordinarily constitutes about two-thirds of the cost of a paint job. Under no circumstances will cold-water paint be used on any building, equipment or property of this company except as specified for walls and ceilings of offices, unless special permission is secured in writing from the *Engineering Department.*

Purchase—All paint will be ordered from the *Purchasing Department;* the requisition must be approved by the industrial engineer of this company.

with grimy hands whereas he would not even be conscious of the fact that he had made finger marks on a wall of darker color.

It is not recommended that white paint be carried entirely to the floor. The lower 5 ft. of the wall does not help to conserve light, not only because it is obstructed by machinery and equipment, but because it receives little or no light from windows or the sources of artificial lighting.

In the writer's opinion there is only one way to apply paint and that is by means of mechanical painting by the air spray or gun. This is largely due to the relative cost of labor and material in painting. According to estimates made by *Engineering News-Record* and based on a survey of $400,000,000 worth of new industrial construction during 1924, about $12,000,000 was spent in painting alone. The paint itself would cost about $4,800,000, or a little over a third of the total painting cost; the remainder, approximately two-thirds of the total, was spent for labor, scaffolding and other miscellaneous expenses.

In repainting old buildings the relative proportion of labor cost would probably be higher because new buildings are generally painted before the machinery, stock, supplies or other material are installed. It will require more labor and time, therefore, on a repaint job than on new construction because it is necessary to paint around the machines and other objects and also to clean up any dirty spots before repainting. This would bring the relative costs more nearly to a two-to-one basis. These figures indicate very clearly two things: First, any attempted economy in painting by the use of inferior materials is absurd, as the gross saving is absolutely negligible even if durability is ignored. Second, the big opportunity to lower the cost of painting is in mechanical labor-saving devices. Of these labor-saving devices, the mechanical painting system is the major one.

Organization for Painting Work in Industrial Plants

In the average factory covering 75,000 sq. ft. or more, of floor area, it would be of advantage to purchase a two-gun, motor-driven outfit which can be kept in almost continuous use. This equipment can be operated by moderately skilled labor with a skilled brush painter following up to take care of piping, window sash, and other equipment which may require touching up. It will be found when this equipment is first installed that a slightly greater quantity of paint will be used but as the operator becomes skilled there will be a considerable saving. The gross saving over hand work should be at least 25 per cent. Other savings can be made which are somewhat indefinite, such as a decrease in the amount of scaffolding required and through the ability of the paint gang to go through various departments during the periods when they are shut down either at night or on holidays.

Where an industrial organization consists of a number of small plants located in different cities, it is better to purchase smaller units of equipment of perhaps only one-gun capacity for each plant, rather than to attempt to use larger units of equipment and ship them around among various plants. It is only by taking advantage of slack periods in various departments and by doing painting at exactly the best opportunity that the maximum saving can be made. If it is necessary to ship the equipment this result cannot be obtained.

Of almost as much importance as the proper selection of equipment and paint is the proper handling of scaffolding and drop cloths. The provision of a sufficient number of these enables one or two laborers to keep this equipment set up ahead of the painters and take it down behind them so that the men actually doing the painting can keep going without interruption.

As in any other painting job, the most important part is the preparation of the work. If this has been done correctly when the surface was first painted, comparatively little preparation is required before spraying. It is not the intention of

Two ways to help the speeding-up of industrial painting.

Here a paint spray is used on the interior brick wall of a building. This work is speeded up considerably by the portable scaffold and also the special and easily-constructed device for holding drop cloths over the windows to prevent paint getting on the glass. It will be noticed that the brush painter has preceded the spray operator and has touched up around the windows and other places which would be covered up by the drop cloths. The construction of this platform, which is on casters, and also the frame for holding the drop cloths over the window, is easily seen from the illustration. The paint container is also mounted on wheels. The compressor is not shown here.

this article to emphasize well-known requirements of good painting. However, it is important that knots, sap and similar defects in wood, as well as scale, pitch spots and the weakness of other materials be properly taken care of.

One of the best methods I have found of sealing up an unsatisfactory surface, such as one that has had creosote applied to it or some stain which works its way through white paint, is to paint it first with aluminum bronze. This will effectually seal up the surface ready for final work. Bronze paints should be applied preferably with a brush.

While the air gun method is used in painting parts of machinery, equipment, automobiles, furniture and other products in production work, it has some limitations when applied to buildings. The simplest surface to paint, of course, is that of a wall or ceiling unobstructed by piping, shafting or other equipment. This sort of surface is, however, seldom met with. The most economical way to paint an obstructed surface is to go right through with an air gun, ignoring the smearing up of piping which is bound to occur. The gang can then be followed up by men with brushes or in the case of large piping, with a small-nozzle gun to touch up the piping.

Some Suggestions on Painting Pipe Lines

The question of pipe color is discussed in a paragraph in the accompanying standard painting specifications. The brush men, whenever possible, should work on the same scaffold with the men handling the painting equipment. This is frequently impossible, however, and as the brush men merely touch up they often work from an ordinary step-ladder, without scaffolding. The illustrations show very well some types of scaffolding and drop cloths which have been found desirable. In addition, it is important that men using the spray method be equipped with a simple type of respirator to prevent the inhalation of paint fumes. The material is in a finely divided state and may cause serious illness if this precaution is not taken.

It is of great advantage to have standard specifications issued for each building, covering exactly the kind and quantity of paint to be used on each class of equipment as well as on the building itself. A sample of the specifications used by this company to cover painting of a factory handling food products is given elsewhere in this article.

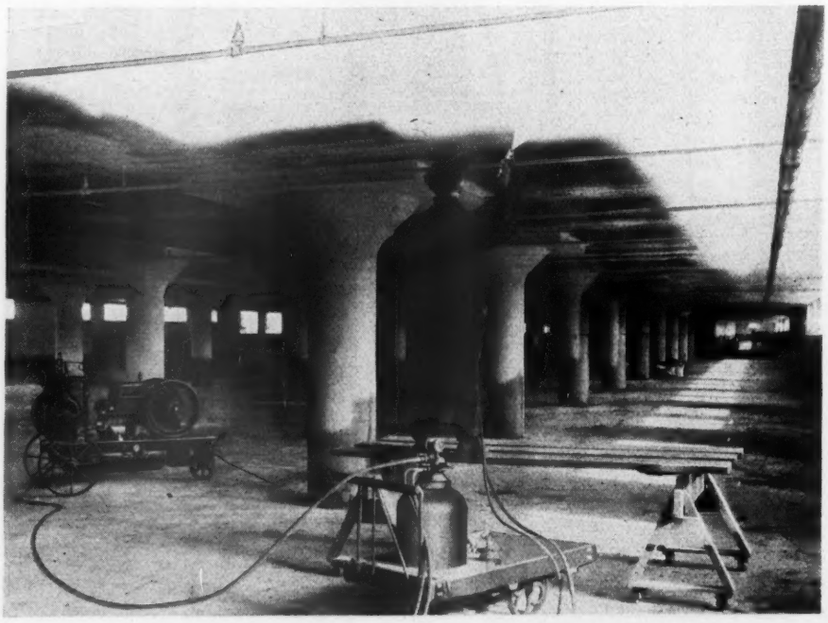
In some instances it is best to classify pipe lines by color, although I believe that this is frequently overdone. With the exception of fire protection lines and pipe lines carrying dangerous liquids or gases it is believed that piping had best be painted the same color as the adjacent structure as it may then be run in with the sprayer without hand work.

If it is desired to combine the advantages of marking as well as spraying pipe lines, conduits and similar structures the pipe line color scheme may be carried out by running it in with a brush, by painting valves or couplings on uncovered lines, or painting bands around covered pipe lines. If this is done the men spraying should skip these bands sufficiently so that the original color will be visible for the man who is to follow up and run them in with the brush. This work must be very carefully checked up, as there might be considerable danger in the use of the wrong color on a line carrying ammonia or other dangerous liquid or gas. This system has been used in a number of central stations and has proved highly successful. As an additional factor of safety it is advisable to tag important valves on lines carrying high-pressure steam, ammonia or other dangerous gases or liquids.

Problems Incidental to Washing Painted Surfaces

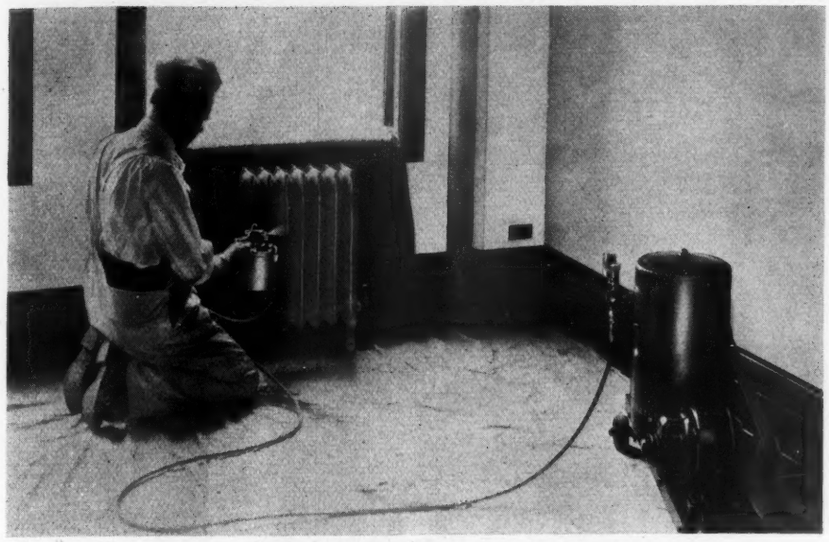
While practically any good mill white paint will stand washing it will be found in the majority of cases that the cost of washing is in excess of the cost of repainting by mechanical methods. The labor cost of washing is higher than the labor cost of spraying and the cost of the necessary cleaning solution plus the extra labor will closely approach the cost of paint. The appearance of a cleaned surface does not, of course, approach that of a repainted surface. In some instances, it is necessary to clean and repaint both, as the surface may be in such condition that a satisfactory repainting job is impossible.

A solution of common washing soda or any of the neutral soda compounds on the market such as Wyandotte Cleaner (J. B. Ford Co., Wyandotte, Mich.) are very good for general cleaning of paint work. Strong caustic alkali solutions must be avoided as they will remove not only the dirt but the paint, as well. In the case of very old paint it will probably be necessary to use a solution of sufficient strength to remove a thin film of paint in order to clean the surface.



Painting the ceiling of a new concrete building.

Notice the ease with which this entire equipment may be moved. The platform is constructed of the proper height for the painter and the wooden "horses" are put on casters. The paint container is placed on a truck so that it also can be easily moved. Even the compressor, which does not have to be moved so much as the other equipment, is also portable. Whenever possible, it always pays to paint a building before the machinery and other equipment are installed. Here the sprinkler lines and other pipes are in and may be painted by the spray or left for touching up by hand as desired.



How a small painting unit is used for follow-up work.

Motor-driven compressor units, such as this, with a small single-gun outfit, are used for painting radiators, pipe lines and for other follow-up work, as well as in small plants which do not require a larger unit. Here the paint is stored in a small container near the gun. Notice particularly how the wall and floor are protected by drop cloths.

The great danger in using a cleaning solution is that it may not be properly rinsed off and that it will continue to act on the paint after painting is completed. Different conditions involve different cleaning solutions. It will be found in some plants that a coating of a definite chemical compound will be formed on the paint due to the nature of the processes in the plant. When this is found to be the case, the best way to lessen the necessity of repainting too frequently is to provide adequate ventilating equipment at the source of air pollution.

Many states require that hoods and suction lines be used in connection with all machines or processes causing or generating dusts or fumes detrimental to the health of the workers. That this has other than health advantages is easily seen.

While this equipment may be expensive in first cost it can soon be charged off, due to the great saving in painting costs through less frequent repainting, and also through the increased illumination due to the better reflecting value of a painted surface which is not covered with dirt. This removal of obnoxious vapors must not be confused with general ventilation. In fact, general ventilation is often responsible for paint discoloration as it tends to spread any fumes before removing them from the building. A satisfactory job of painting cannot be done on a surface which has been coated with material of this sort, particularly if this material is a paint repellant.

In many industries it is necessary to wash paint frequently for sanitary reasons. This washing will generally be required only on the lower 6 ft. of the wall. Where this is the case a dado should be painted of a high-grade, water-resisting paint or the ordinary wall paint may be used and this dado given a coat of spar varnish. In these buildings it is much more satisfactory to have this wainscoting made of white enamel brick, tile or glazed brick as no paint will stand the frequent washing required in factories handling food products. The necessary number of such washings may be decreased by placing machinery and equipment a sufficient distance from the wall to prevent spattering.

With the labor cost such a high percentage of the cost of paint, emphasis must once more be placed upon the desirability of using not only good, but suitable material. Cheap paints contain inert, inactive and useless material of various sorts which cause the surface to break down and discolor rapidly. In addition, good paint improperly used will give poor results. Paints subject to fumes of a chemically active nature should be of the so-called chemical or fume-proof variety which are put out by a number of reputable manufacturers. The use of this type of paint, however, must not be misunderstood. While fume proof to the extent that the paint itself will not combine with gases and discolor, they are, of course, not proof against the accumulation of mechanical coatings which give the effect of a discoloration. These coatings can be removed by cleaning, whereas another type of paint unsuitable for this use would in itself undergo a chemical transformation so that no amount of cleaning would restore its original color.

Why It Does Not Pay to Use Poor Quality Paint

As an example of good and properly selected paint, I have in mind two roof ventilators erected at about the same time and subject to the same atmospheric conditions. One was painted with red lead, the other simply with black paint. Since no specifications were furnished the paint was presumably nothing more than lampblack with a binder of some sort. Neither ventilator received any further attention. At the end of three years the ventilator covered by black paint was completely rusted and required replacing. The ventilator which had been painted with red lead appeared to be in as good condition as when first erected. This is rather an extreme case perhaps as it involved not only the replacement of the paint, but the entire replacement of the equipment in addition. The cost of the red lead over the black paint amounted to only a few cents. The cost of the new ventilator was about $45. In this connection it might be said that the use of the paint gun is one of the best methods of painting structural steel, the intricate details of which are sometimes very difficult to reach with a brush.

The writer has formed rather definite opinions as to various brands of paint available for interior and exterior use and is absolutely convinced there is no better way to spend money than on high-quality ingredients. There are a large number of excellent brands of paint on the market and the purchaser can make no mistake in purchasing any one of these reputable brands. Hand-mixed paint, at least in so far as required for industrial work, is a thing of the past, as it is absolutely impossible for a painter to properly mix the ingredients on the job by hand. Most paint manufacturers have a service department which will be glad to take up in detail any particular problems which may arise. This service should be freely used by industrial men.

COILS THAT ARE diamond shaped as well as those consisting of straight bars connected by involute end connectors are used in turbo-generator windings. Both kinds of coils are shown in the accompanying illustrations together with typical winding diagrams showing how the coils are connected to form the completed winding.

Methods for Taking Data on

Turbo-Generator Windings

Together With a Description of Single-Layer, One-Bar-Per-Slot Windings and Two-Layer Lap Windings as Used on These Machines

By A. C. ROE

Renewal Parts Engineering Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

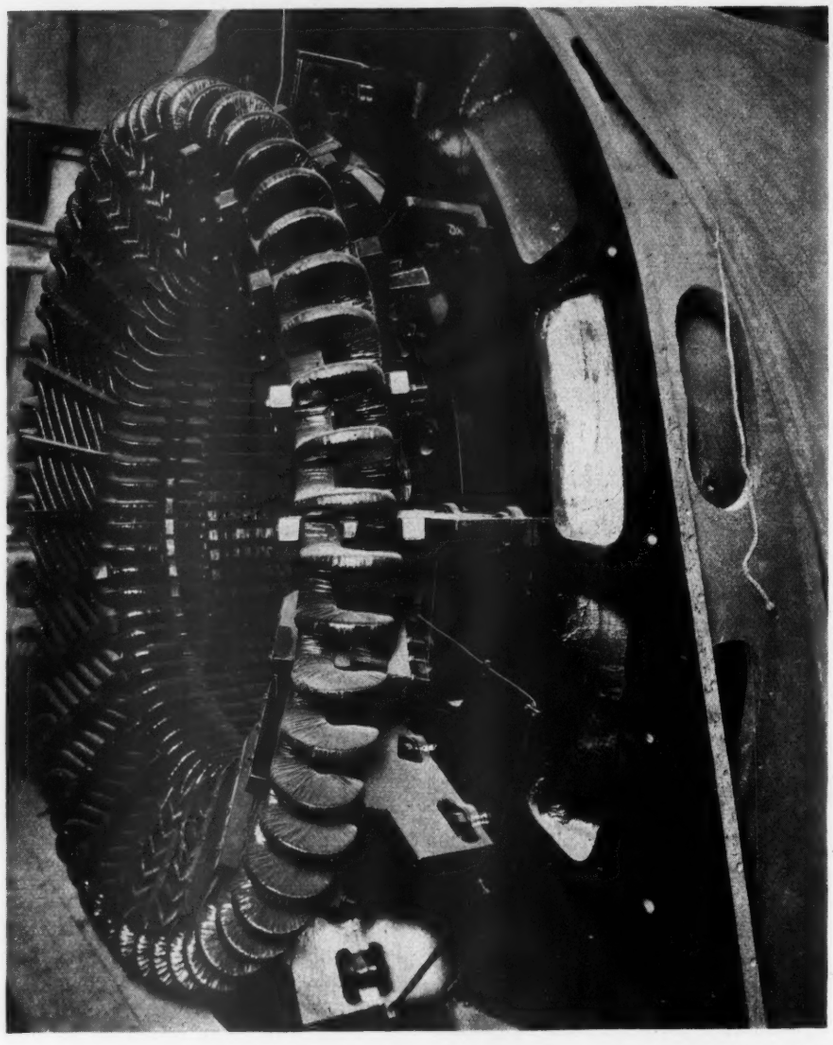


Fig. 1—Showing the method of bracing used on a turbo-generator winding.

The end turns are held between insulated braces which are bolted together and to the stator of the machine. This is necessary in order to protect the end turns from torsional strains set up by short-circuits that may occur on the machine. This illustration shows the rear end of the winding, which has no group or phase connections.

IN THE two preceding articles of this series we have discussed one-coil-per-slot lap and wave windings, as well as one-bar-per-slot wave windings. In this article, we will take up one-bar-per-slot lap windings. These are mostly used in turbo-generators. Inasmuch as turbo-generators are also wound two-layer in the slot section, we will also consider this method of winding.

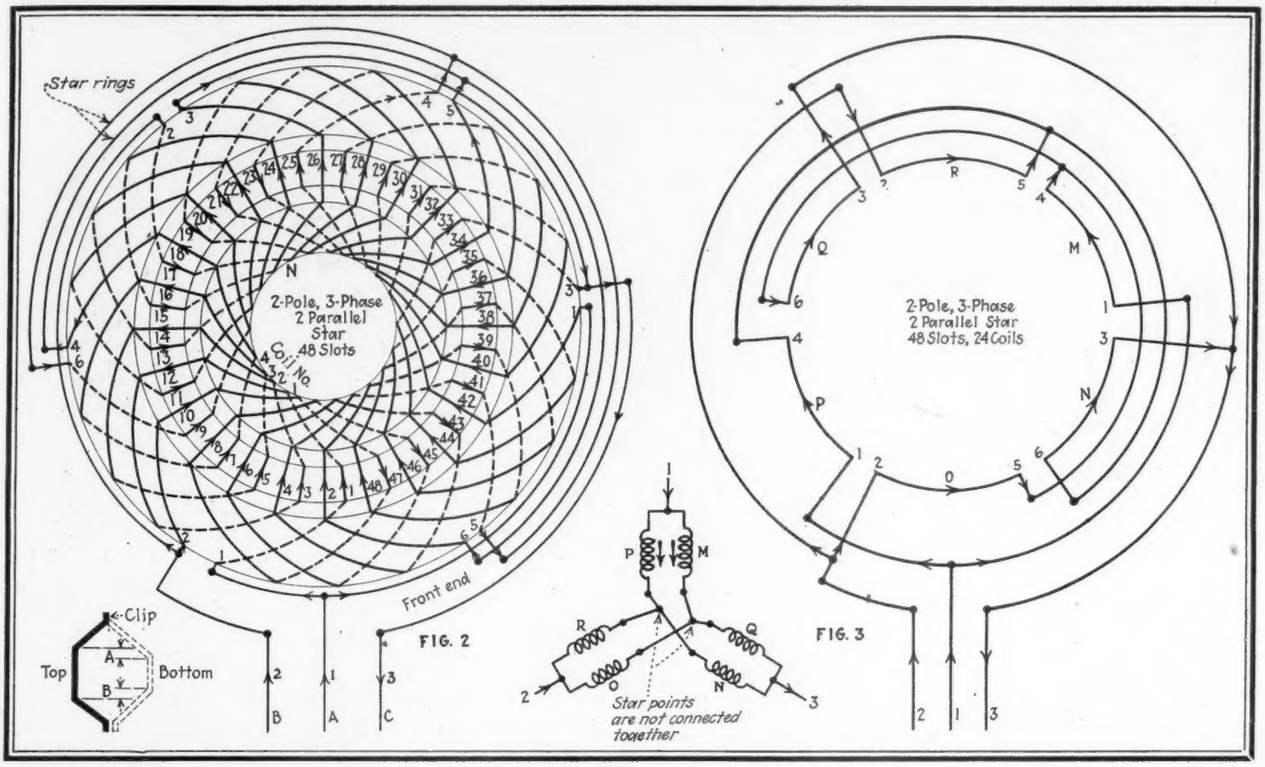
Turbo-generators generally use diamond-shaped coils, consisting of two half-coils, each half-coil being composed of one slot section at the two ends of which are the end pieces. Another type of coil used in the smaller turbo-generators uses an involute end connector.

Let us first consider a single-layer, one-bar-per-slot winding, as applied to a two-pole, turbo-generator stator. In Fig. 2 is shown the connection diagram for a 48-slot, two-pole, three-phase stator having 24 coils; that is, there are 24 long half-coils and 24 short half-coils. The ends of the half-coils are placed in two layers; that is, the ends of the half-coils having the short slot section will underlie the ends of those having the long slot section. The ends of the half-coils are joined together with clips and soldered and insulated as shown in the sketch at the lower left of Fig. 2.

In a lap winding of this type, the number of pole-phase groups equals the number of poles multiplied by the number of phases, which in the winding under consideration equals 2×3=6 pole-phase groups. The number of coils per pole-phase group is equal to one-half the total number of half-coils divided by the number of pole-phase groups which, for this winding, will equal (48÷2)÷6=4 coils per group.

WINDINGS HAVING one coil per slot and one bar per slot were discussed in the first two articles of this series, which were published in the January and March, 1925, issues of INDUSTRIAL ENGINEER. In this article, Mr. Roe takes up one-bar-per-slot windings as used in turbo-generators and also describes and gives the diagrams for two-layer windings that are often used in these machines.

In this type of winding the full back pitch must always be odd and equal the odd number nearest to the quotient of the total number of half-coils divided by the number of poles. Since there are 48 half-coils and two poles and 48÷2=24, the full back pitch for the winding will be 23 or a pitch of 1-and-24. However, the back pitch generally used runs from 50 to 70 per cent of the full back pitch; hence for this winding the



Figs. 2 and 3—Here are the diagrams for a one-bar-per-slot lap winding used on a turbo-generator.

Fig. 2 shows the complete winding diagram for this machine. The phases are connected to form two independent star connections with the line ends connected in parallel. Fig. 3 shows the line diagram for the same winding. In this diagram, the pole-phase groups are indicated by the arcs M, N, O, P, Q and R. At the lower left of Fig. 3 is a simplified diagram showing how the groups M, N, etc., are connected two-parallel-star.

back pitch will be $0.50 \times 23 = 11.5$ or a pitch of 1-and-12.

Let us start the A phase of this winding in slot *1*, as shown in Fig. 2. Using a back pitch of 1-and-12, the winding will continue from slot *1* to slot *12* and thence back to slot *3*; then through slot *14* and back to slot *5*, from which it goes to slot *16* and back to slot *7*. It then goes to slot *18*, after which it goes to the star point. In going through this much of the winding, we have traveled through a series of four coils, which forms a pole-phase group.

In putting the arrows in this diagram the two-in-and-one-out check is used, as has been explained in previous articles. In Fig. 2 line leads *1* and *2* are taken as going in and line lead *3* is taken as coming out. This scheme is followed throughout this diagram. The arrows are also inserted in this manner in Fig. 3, which is a line diagram for the winding shown in Fig. 2. In Fig. 3 the pole-phase groups are marked *M*, *N*, *O*, *P*, *Q* and *R*. The polarity of the pole-phase groups can be checked by the two-in-and-one-out check.

In Fig. 3, the beginning and end

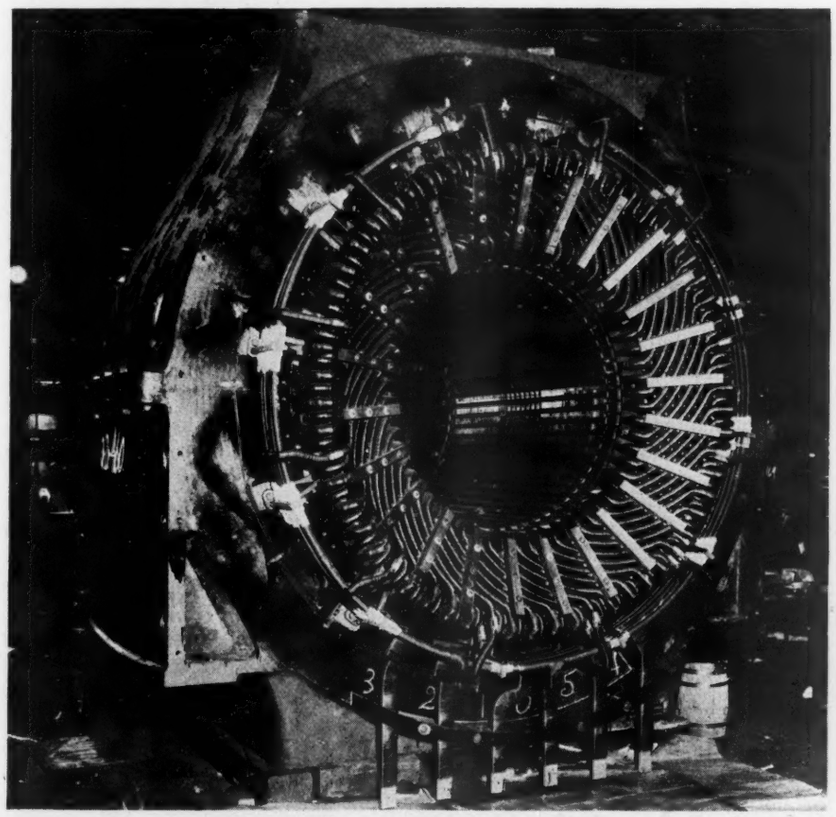
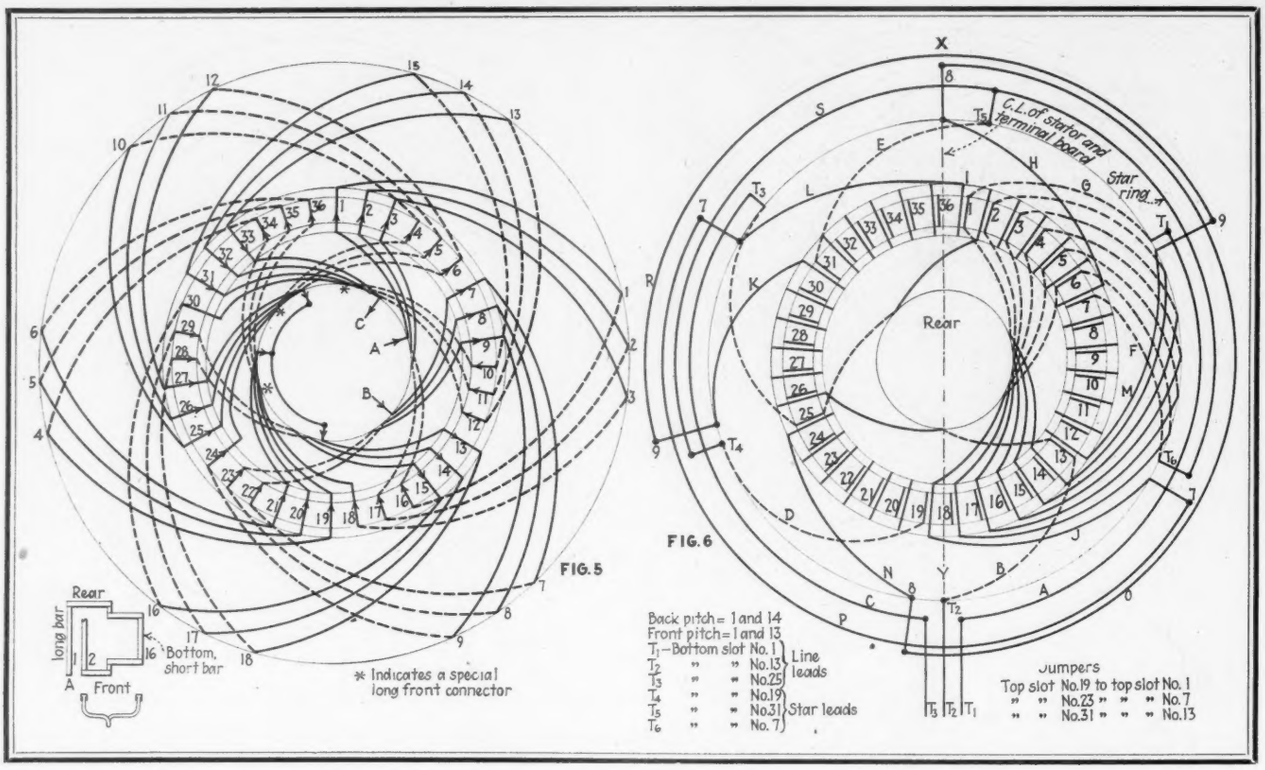


Fig. 4—The manner of making the connections between pole-phase groups can be clearly discerned in this illustration.

This turbo-generator has a two-layer lap winding using diamond-shaped coils. Further details of the connection scheme for this kind of winding are shown in Fig. 6. Notice the marking used to lay off the winding. Careful inspection will show that coils 46, 51, 58, etc., are marked with their numbers; also the leads are marked 1, 2, 3, etc.


Rear
long bar
Front
Bottom, short bar
* Indicates a special long front connector
FIG. 5
X
C.L. of stator and terminal board
Star ring
Rear
FIG. 6
Back pitch = 1 and 14
Front pitch = 1 and 13
T1 — Bottom slot No. 1
T2 " " No. 13
T3 " " No. 25
T4 " " No. 19
T5 " " No. 31
T6 " " No. 7
Line leads
Star leads
Jumpers
Top slot No. 19 to top slot No. 1
" " No. 23 " " " No. 7
" " No. 31 " " " No. 13

Figs. 5 and 6—Study of these two diagrams will give a clearer understanding of one-bar-per-slot lap windings and two-layer, lap-wound, turbo-generator windings.

In Fig. 5 is shown a one-bar-per-slot lap winding for a 300-kw., two-pole, three-phase, 60-cycle machine having 36 slots. Involute connectors requiring three ranges are used for making the end connections. The third range, which has the extra long bar, is used only for making the connections between pole-phase groups. The phases of the winding are connected in series-star. Fig. 6 shows a two-layer lap winding for a 2,250-kva., 4,600-volt, two-pole, 3,600-r.p.m., three-phase, 60-cycle, turbo-generator. Thirty-six diamond-shaped coils, which are made up as half-coils, are used in this winding. The letters in the diagram indicate the 17 different sizes of connectors and rings that are required for making connections between coils.

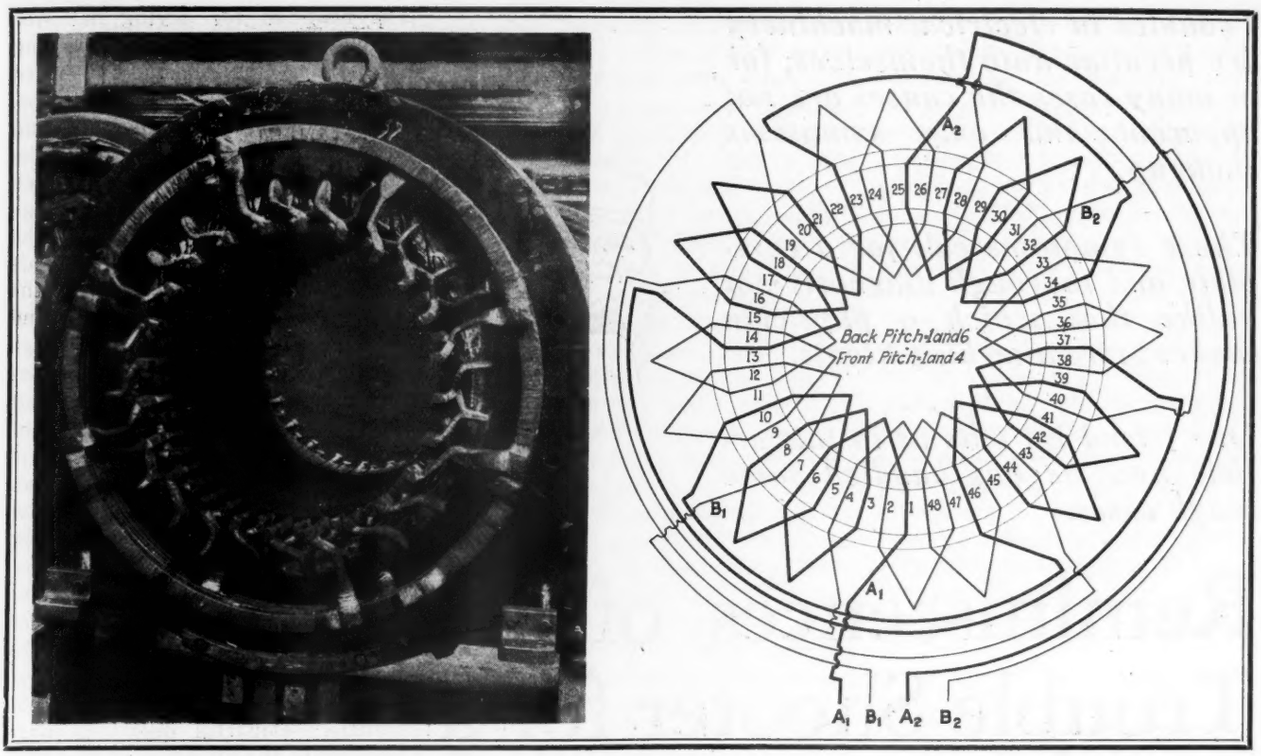
of each pole-phase group is marked with a connection number which corresponds to the connection number at the beginning and end of each pole-phase group in Fig. 2. This is done to identify and locate each connection. In this type of winding the connectors are made of bar copper bent on edge in a ring shape. These rings are supported by brackets which are fastened to the stator frame. Specially-shaped connectors are used to make the connection between the coils and jumpers; hence the need for some means of locating each connector with reference to its ring and slot.

At the lower left of Fig. 3 is shown the schematic diagram for this winding. The pole-phase groups in this diagram are lettered to correspond with those in the main diagram. Inspection will show that the winding is connected two-parallel star. However, the pole-phase groups are not directly paralleled, but one set of three pole-phase groups is connected to form one star and the other set of three pole-phase groups is connected to form the second star. The line ends of the two star connections are then connected in parallel.

In the second article in this series, published in the March, 1925, issue of INDUSTRIAL ENGINEER, wave-wound, one-bar-per-slot windings were discussed. Before considering the two-layer, lap-wound, turbo-generator windings, we will digress for the moment and take up lap-wound, one-bar-per-slot windings having involute end connectors. With the exception of the end connectors, this winding is quite similar to the windings that we have just considered.

Such a winding is shown in Fig. 5. The A phase is started at the front end of the bar in slot *1*, and goes through the bar in slot *1*, which is connected at the rear to the bar in slot *16*. The back pitch is, therefore, 1-and-16. The method of making the involute end connection between bars *1* and *16* and between bars *16* and *2* is shown at the lower left of Fig. 5. The front end of the bar in slot *16* is connected to the front end of the bar in slot *2*; the rear end of this bar is connected to the rear end of the bar in slot *17*, the front end of which is then connected to the front end of the bar in slot *3*. The rear end of the bar in slot *3* is connected to the rear end of the bar in slot *18*. It can be readily seen that we have gone through a series of three coils which started in slot *1* and ended in slot *18*. This series of coils constitutes a pole-phase group. It will also be noticed that the bars in slots *1*, *2* and *3* are long bars whereas the bars in slots *16* and *17* are short bars. The top halves of the involute end connectors connect to the long bars and the bottom halves of the involute end connectors are connected to the short bars.

It now remains to connect the pole-phase group, through which we have just traced the winding, with the second pole-phase group for this phase. Inspection of the diagram will show that the bar in slot *18* must be connected to the bar in slot *34* by a pitch of one slot more than the regular front pitch. The bar in front of slot *18* is an extra long bar and is connected by means of an involute end connector to the front end of the bar in slot *34*. The winding continues through the second pole-phase group for this phase, through slots *34*, *19*, *35*, *20*, *36* and *21*. The front end of the bar in slot *21* is connected to the star point. The



Figs. 7 and 8—Lap winding for a two-phase turbo-generator having one bar per slot and using involute end connectors.

Fig 7 shows the arrangement of the bars, the involute end connectors, and the group jumpers, which are the bar rings surrounding the winding. Fig. 8 shows the winding diagram for this machine. One phase is drawn in heavy lines to enable you to check the circuits more easily. It will be noticed that the machine has 48 slots and bars, four poles, six slots per pole per phase, and three coils per group.

winding for the B and C phases is connected in a like manner, the extra long bars falling in slots *24* and *30*, respectively.

In taking rewinding data on this type of winding, care must be exercised to mark the slots which contain the special bars and also the slots to which the leads connect. The winding data is taken as follows:

(1) Call any one line lead A_1.

(2) Mark the slot to which the lead connects as slot *1*.

(3) Counting clockwise, the data would be as follows:

(a) The line leads will connect to long bars falling in slots *1*, *7* and *33*.

(b) The star connectors will connect to long bars falling in slots *13*, *21* and *27*.

(c) The extra long bars will fall in slots *18*, *24* and *30*.

(d) The special, long-pitch, involute end connectors will connect together the bars in slots *18* and *34*, also the bars in slots *24* and *4*, and the bars in slots *30* and *10*.

(e) Starting with slot *1*, the distribution of long, extra long and short bars will be as follows: 3 L, 3 S, 3 L, 3 S, 3 L, 2 S, 1 EL, 3 L, 2 S, 1 EL, 3 L, 2 S, 1 EL, 3 L, 3 S. In the above S refers to a short bar, L refers to a long bar, and EL refers to an extra long bar.

(f) The back pitch will be 1-and-16.

(g) The front pitch will be 1-and-15.

(h) The special front pitch used in connecting the extra long bars will be 1-and-17.

By marking the slots and recording the data as shown, it will be found that a wiring diagram will not be needed. When marking the core, mark the teeth on either side of the slot that is desired to be located. Also, check the line of the center lead with the core, that is, the center line of the terminal block. The winding that we have just discussed gives a good appearance and is easy to connect and wind.

A one-bar-per-slot lap winding using involute end connectors, as applied to a two-phase turbo-generator, is shown in Figs. 7 and 8. Fig. 7 shows the arrangement of the bars and the involute end connectors. The group jumpers are the bar rings that surround the winding. In the winding diagram for this machine, which is shown in Fig. 8, one phase is drawn in heavy lines to enable you to check the circuits more easily. It will be noticed that the machine has 48 slots and bars, 4 poles, 6 slots per pole per phase, and 3 poles per group.

We will now take up two-layer windings as used in turbo-generators. Such windings are lap wound, using diamond-shaped coils, each coil consisting of two half-coils. In Fig. 4 is shown the connection end of such a winding for a turbo-generator. The circular rings that are made of heavy bar copper and encircle the end of the winding, are used for making the lead and jumper connections. The rear end of a turbo-generator winding is shown in Fig. 1. In both of these figures, notice the method of bracing that is used to hold the end turns of these large coils in place. This bracing is required to keep the end turns from being twisted in case the machine is short-circuited under load.

A working diagram for a 2,250-kva., 4,600-volt, three-phase, 60-cycle, two-pole, 3,600 r.p.m. turbo-generator is shown in Fig. 6. This machine has 36 slots and 36 coils which are two-layer lap wound. In this winding, the phases are connected series-star, a progressive winding being used. Only one full phase group is shown connected in the diagram. However, the line leads, star leads, and jumpers are all shown.

Reference to Figs. 4 and 9 will show that the terminals of the machine are located at the bottom and center of the stator. This location is used in the diagram in Fig. 6. The vertical center line of the machine passes through the center terminal and between slots *18* and *19* and slots *36* and *1*.

(*Please turn to page 209*)

Troubles in electrical machinery are peculiar unto themselves, for in many cases the causes are not apparent and only symptoms show up.

* * *

These symptoms call for a complete and thorough diagnosis not unlike that which a physician makes in treating his patients.

* * *

Our friend Ed tells us in this article how he has handled some tough cases.

Reminiscences of a Trouble Shooter for a Machinery Builder

Sketches from an interview by

Practical Pete

IN THE March issue, I related some of the things friend Ed told me in a recent interview about his job as an inspector for a large machinery builder. In this article I shall continue our discussion of the things talked about and refer particularly to some troubles that Ed brought up because they called for some fast thinking, some ingenuity, and a lot of common sense. I will pick up the thread of our conversation at the point where it was cut off in the March issue.

"From your experience as a trouble shooter, Ed, you must have formulated some rough-and-ready rules on what to do first on a trouble job when the symptoms are puzzling and do not clearly indicate the cause or location of the difficulties. Let's have some of those experiences," I suggested.

"Well, I guess that's so," said Ed. "But just how to lay down rules of procedure is a hard thing to do, for 'most every trouble is searched out by a process of investigation and elimination of this or that possibility until the vital spot is located. It takes experience and a practical knowledge of the apparatus you are working with to know just what to do first. I can probably best illustrate what I mean by some more details of my own experiences on particular jobs.

"Thanks to an old timer, I learned two things at the beginning of my electrical work that are very often true in diagnosing trouble. The first axiom of this particular old timer was: 'Remember that 90 per cent of electrical trouble is mechanical.' His second one was: 'Beware of simplicity in looking for trouble.'

"I really believe that his first axiom is generally true, for I have often spent much time and trouble and have seen others do the same, trying to fathom the intricacies of electricity from the fundamentals to Steinmetz, only to find the trouble in a mechanical area. To cite an instance, I recall my first erection job. It called for the installation of a generator (three-phase, 2,300 volts), switchboard, and three-phase, 2,300-volt transformers to parallel with a two-phase 460-volt outfit. I was instructed by the office to have everything in readiness for a test run to be supervised by an older engineer who happened to be in that territory. The heat-run for drying out was completed and I was just making connections for phasing-out when this engineer arrived on the scene. He made a number of inquiries and we went over the installation in detail to the point of phasing-out, when he asked if I had noted the voltage delivered on the low side of the transformers for the new job. This I had not done, but we brought the outfit up to synchronous speed and took the most unbelievable readings possible to take. I do not recall what they were at the present time, but an unbalanced condition existed of about 150 volts in the phases and much more than that between phases.

"I was distracted and 'all in' after a fatiguing drying-out run and the supervising engineer was also puzzled, to say the least. Between the two of us we thoroughly analyzed the board, the machine, and the transformers, but not a thing was found to create a suspicion of the trouble. Doubtful questions were brought to the attention of the office engineers, but this did not help us in the least. Here was a prize jinx if there ever was one.

"This engineer had arrived about 10 o'clock in the morning. About 6 o'clock that night while making another examination of the switchboard, we discovered after removing the short-circuit wire immediately above the oil switch, that one of the outgoing lines to the transformer had not been reconnected to the switch, with the result that the transformer was being fed by only two wires from the generator. It was at this point that I was working when he arrived on the job. A fatigued body and an excited brain account for the oversight that commanded a whole lot of attention for over a half-day. All of this brings the first, if not both, of Old Timer's axioms to the front. As an indication of how the supervising engineer felt about the matter, I might relate that he took it good naturedly with the exclamation that, 'The drinks are on me.' Whether or not he discovered that I knew at least a few electrical terms, or had used this as a bribe to keep the account of our trouble and his half-day worry from other engineers, I do not know, but he turned in a very good account of the installation."

"But," said I, "not all electrical troubles can be traced to mechanical faults of operation or construction. How about the human errors of over-

sight and just natural mistakes in following blueprint connections?"

Ed thought a minute and then said:

"If a trouble shooter or service man keeps the first axiom in mind it is very unlikely that the second one will bother him, but it has tripped me on different occasions and it was on one of these occasions that a man of little training discovered the error. One instance was in connection with a bad board. This board was of the automatic type, controlling a large synchronous motor. During the course of erection, I found the blueprint and the board at outs and I was practically at outs with both of them. It was a rush job. The ever-present officials were present accompanied by others from district and general offices and it was hot and dirty, and everything was about as 'cockeyed' as it could be.

"It is my plan to wire according to the blueprint. If it is wrong I cross my bridges when I get to them. If it is right, I feel happy. This I had done in this particular case and when the starting button was pressed I expected most anything to happen. It did! The most silent board I ever saw looked me in the face, as did every official, looking more officious than ever. I left the juice on the board and tried out various relays which were OK, as individual units. This did not help much; so I began at the starting button to trace out trouble and I can truly say that I never did see such a mixed-up outfit. It was during my survey of the trouble that the company electrician began an investigation and at the starting button found a wrong connection. This button was so designed that it had two entrances with a cross-connection necessary for use as a single connector. I had passed up that item, due to my knowledge of what I could expect from such a board as learned in its erection. Nevertheless, it is the little item such as this one that is more than likely to trip up the service man and not the practical chap who cannot see beyond points close to his nose. This is no reflection on these chaps, for the great majority are the best of fellows."

"Now, here's a touchy point, Ed, that comes to my mind in connection with these mechanical troubles, on which I should like to get your comments. In running down troubles charged to the equipment made by your company, you must have bumped into troubles in other makes of equipment used with yours that were either the real or a contributing cause of the trouble you were called to remedy. In such a case just how do you proceed?"

"Such cases come up frequently," was Ed's reply. "Such a mechanical trouble comes to mind in connection with a new installation for a large manufacturer who had installed an automatic station for charging batteries in his fleet of trucks. This firm had purchased an automatic board from a reputable manufacturer and a motor-generator set from our firm.

"The switchboard was erected by the customer, and when it came time to test them out, there was no service—rather, I should say, there was peculiar service. The motor would at times attempt to start and the board would attempt to function, but on only one occasion out of numerous attempts did both of them function correctly and then the service was of very short duration, for the motor stopped. Further attempts were useless. The switchboard men claimed their product was OK, and blamed the motor.

"The above information on the case was given to me on my arrival. A talk with the switchboard men disclosed the fact that they evidently knew their board and it was correct as far as they could tell from the blueprint and their experience. I made a casual inspection of the motor and generator, but nothing appeared out of the ordinary. Further starting attempts were made and we were fortunate in getting an attempt to work, with the usual stop. This was sufficient to form an idea in my mind, from what had been related and the short observation I had made, that we were enjoying a loose contact somewhere on the d. c. end of the motor-generator set or the connections of this set to the switchboard. Tests were made and a loose connection was found in the shunt field. The wire was in its keeper, but the retaining screw had never been tightened at the factory. Paint from the spray gun had lodged in the opening, serving to insulate it, with the result that no excitation was apparent at the switchboard for the operation of the board.

"Here is another mechanical ailment which has to do with a manufacturer and his apparent trouble with a small auxiliary generating set. This set operated from the time the works closed at night until work was resumed in the morning, during Sundays, holidays, etc. It served to keep the sprinkling system from freezing, to provide night lights, and to operate the machine shop air compressor and other auxiliaries which included a number of fans. The generator rating for this output was barely enough to handle the load, but according to the manufacturer it would do so. Various load tests on individual units and circuits were made and the outfit behaved badly. As a matter of fact, it would be unsafe to leave this large woodworking plant to depend on this outfit to keep its heaters in proper service in the event of extremely cold weather.

"Load tests brought us to the output test and we soon found the trouble to be insufficient steam pressure to develop the full power of the prime mover. The pulley was too small, with a correspondingly small belt to transmit the power, with unnecessary apparatus on the pulley shaft resulting in too much friction load. To end this incident a larger set was recommended."

"Another kind of trouble," I remarked, "that seems to me you have to handle more as a diplomat than as a trouble shooter, are those cases where the operators are sure that the troubles are not due to changes or repairs that they have made. Tell me how you have handled some such situations."

"A very frequent trouble of this nature has to do with interpoles," Ed replied. "Wrong connections are easily discovered on the test floor of the manufacturer and are quickly corrected. But many times the customer desires to make changes in his machines to take care of some particular operation of his own and, as a consequence, changes his motor to suit the requirements. The results are like the situation presented to me last fall. After such a change was made, the usual trouble of reversed interpoles presented itself and efforts were made by the electricians to correct it, with unsatisfactory results. Correspondence with the manufacturer followed, but the trouble persisted and it was finally decided to call in the service man. The plant men insisted that they had done everything to correct the trouble, and from their explanation it seemed as if they were right.

"An investigation, however, showed that they had merely changed the

connections of the interpoles and had not reversed them. The simple test to discover the facts for this motor was to run it as a series motor and note the rotation. This had to be done with care as excessive speed is only a matter of a few seconds. The series connections were then removed and it was tried out as a shunt motor, in which case the direction of rotation must agree with that of the series connection. If it does not agree, reverse the connections until it does agree. Then connect as a compound interpole motor and check the polarity of the interpoles with a compass or with a piece of iron. The relation of the interpoles to the main poles in a motor of clockwise rotation is such that when the main pole corresponding to 12 o'clock agrees with the interpole corresponding to 1 o'clock, the connection is correct. If it does not, the connection must be reversed and to reverse this connection means reversing the interpole connection. The interpole connection is usually made permanent in the factory and is inside the motor. To make the change usually requires unsoldering this connection and making a new connection with the proper change.

"In order to simplify the relationship of interpoles to the main poles, I present here a diagram from my notes which is well worth the trouble of preserving. Acknowledgment is made to the author, D. H. Braymer, for the use of this diagram, which appears in his book 'Armature Winding and Motor Repair.'

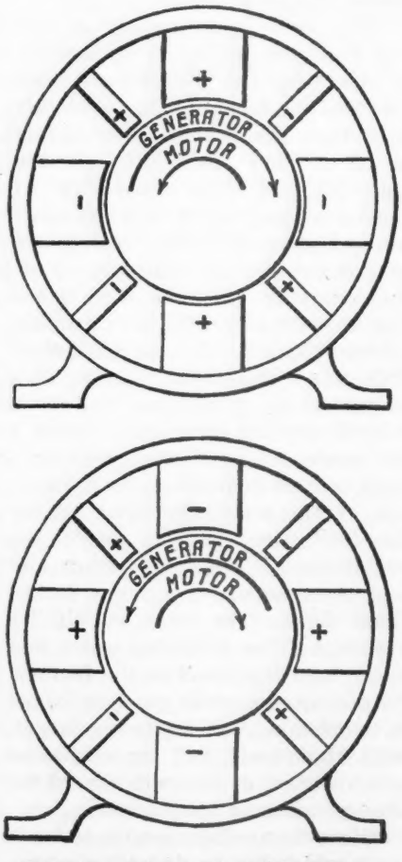
"The foregoing has been a hasty review of difficulties that may arise from what may be termed 'mechanical troubles.' It has been my practice to look for mechanical troubles first, for most of us are prone to consider all troubles with electrical apparatus as purely electrical and we make a big noise trying to make a mountain out of a molehill. Anyway, it is an idea well worth trying."

"Now that you have proved your point about these mechanical troubles, tell me, Ed, about some of those sneaking electrical troubles that act like fleas; that is, just when you think you've caught them, they've hopped to another place."

Ed got this point and came back with the following experience:

"I recall such an instance involving a constant-current transformer which gave us much concern when I was in a power house. This transformer was made by a well-known manufacturer and rated at 25 kw. It was connected to a street lighting circuit of 12 kw. and used to get so hot that its operation was hazardous from our point of view and we shut it down. This happened a couple of times and we finally tore it down to see whether or not any packing was left in the case or the operating mechanism damaged in any way, but such was not the case. As this was one of the plants under my jurisdiction I requested one more trial, but got no better results and the matter was called to the knowledge of my superiors.

"With the operating engineer and the maintenance chief directing a test, we found the output to be slightly over 12 kw. and the input nearly 21 kw., the loss being 8.64 kw. There was no plausible explanation of this. Accordingly a service man was called and he said the transformer was OK after he had given it a complete test. He also ascribed its action to aging of the iron with the explanation that this was the usual case under existing conditions. Somehow or other I was still skeptical of this proposition, but we put it in service and left it in service. It finally got tired of getting all 'het up' about having to work every night and as far as I know gave us no further trouble.



Polarity of interpoles with relation to main poles for direction of rotation as motor and generator.

"Commutators are sometimes a source of trouble and a good place to get into trouble is during repair and in the after-effects. It is of the latter that I will speak, referring to a large commutator that was repaired in the field. Commutators have an 'aging' process of their own which is completed before they leave the factory and if it is at all practicable they should be repaired in the factory.

"This particular commutator was repaired and immediately put in service because the customer needed his machine badly. He was told that the commutator would require further treatment before it would be in good condition, for it was a 'green' commutator. So far so good, but it was only a matter of time until the customer wrote a very uncomplimentary letter to the manufacturer about his products and his service men, due to the fact that he had not taken care of his machine during the seasoning process. After this machine had been in service long enough to heat the commutator thoroughly, it should have been shut down periodically and the commutator checked, nuts tightened, etc., with special attention given to the mica insulation. This would have given him a good commutator with no further repairs and no reason to berate the manufacturer and his service men.

"Heating of the commutator for seasoning is accomplished in various ways, such as wrapping it with asbestos and using a heating element, actual service, and by using wooden brushes. Circumstances make one or the other of these methods applicable to a particular case, but I have found that where it is possible to economically operate a machine without load, that the last method is the best. It consists of making brushes of hard wood the same size as the regular brush, placing them in the brush holder under high tension and running the machine. This method has the advantage of seasoning a commutator under conditions of actual operation, especially as regards centrifugal force. It also presents an exaggerated idea of brush loss.

"While on the subject of commutators I might say that the grinding in of brushes on a large commutator

(*Please turn to page 212*)

What Happens During

Single-Phase Operation of Polyphase Motors

Together with Experimental Data Showing the Changes That Take Place and How Motors May Be Protected from Damage Due to Such Causes

By R. G. WARNER
and W. B. HALL
Electrical Engineering Department, Yale University

WHAT HAPPENS when a fuse blows in one wire of a three-wire line feeding a three-phase induction motor? When one wire is interrupted, by a blown fuse or otherwise, the motor will continue to run, single phase. This occurrence is the cause of a large proportion of industrial motor failures, or "burn outs," and the answer to the above question is of great importance to every plant engineer. In this article Mr. Hall and Mr. Warner tell just what changes take place in the load placed on the windings of both star- and delta-connected motors and also give methods of protecting motors against damage from such causes.

WHEN one wire of a polyphase circuit is interrupted, by the blowing of a fuse or otherwise, the motor will continue to operate. The speed will drop perhaps one or two per cent, depending on how heavily the motor is loaded. This is a barely perceptible amount. The slight change in humming is not distinguishable through the other noises in an industrial plant; so the operator keeps on using the motor, and does not know that any change has taken place.

Although the motor will continue to run single phase, if it is already running when the circuit is broken, it will not start single phase. When an attempt is made to start the motor after it has been shut down, it will hum but will not start. The operator then knows that something is wrong and the trouble will be found and remedied. However, with many present-day, "across-the-line" starters, the starting position of the handle short circuits the fuses that protect the motor, in order that the starting-rush may not blow them. If one of *these* fuses has blown, it will be shorted out during starting, and the motor will start normally on all three phases. When the handle is thrown to "run" the fuses are placed in circuit, and the motor runs single phase. With a starter of this type, the motor might be used indefinitely with one fuse blown, and the operator be unconscious of the fact.

Assume that a three-phase motor is carrying its full rated load. Then, during three-phase operation it will draw its rated current. Running single phase, it will be carrying the same load. Therefore, it must draw the same total power. This will require a current that is slightly more than 1.73 times as large as before. This may be sufficient to blow the remaining fuses. If it does, the situation is cared for. But quite often the fuses are heavy enough to permit of momentary overloads on the motor, which is quite allowable, and this current will not blow them. Then what happens in the motor? This depends on whether the motor is connected star or delta.

If the motor is star connected, as is shown in diagram *X*, the windings of one phase will be carrying no current, and the windings of the other two phases will be carrying 1.73 times normal current. If this continues, eventually these windings will overheat and burn out.

If the load is less than full load, all these currents will be cut down proportionally. If the load is 58 per cent of normal full load, the star-connected motor will have normal line current and normal winding current, and be able to operate indefinitely without overheating.

If we had fuses or other protective devices in the line which would just carry normal current, and would blow if that value were exceeded, the star-connected motor would be safe against damage due to single-phase operation.

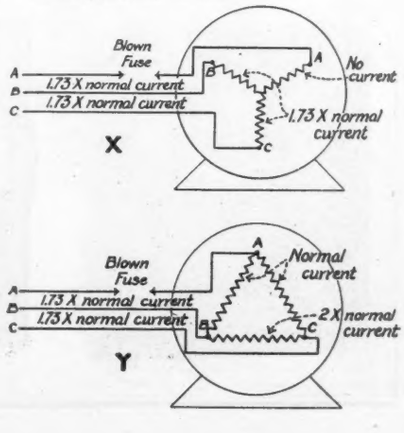
If the motor is delta connected, as is shown in diagram *Y*, the line current will be the same as in the previous case; that is, there will be no current in the interrupted line and 1.73 times normal current in the other two lines. But this current will divide between two internal paths in inverse ratio to their impedances, so that one-third of this current will pass through two windings, and two-thirds will pass through the third winding, that is, ⅓ of 1.73=0.58 or 58 per cent of normal current will pass through two of the phase windings while ⅔ of 1.73=1.16 or 116 per cent of normal current will pass through the third phase winding.

Normal current for these windings is 58 per cent of the normal line current; therefore, the two lightly-loaded windings will be carrying their normal, full-load current, but the winding across the active phase will be carrying twice its normal current. This is a worse condition than in the star-connected motor; so the delta-connected motor will be even more likely to burn out.

In the delta-connected motor, if the load is 58 per cent of normal full load, the line current will be normal, but the current in the active phase winding is 1.16 times normal

These diagrams show the amount of overload placed on windings of three-phase motors that are operating single phase.

In the star-connected motor shown in diagram *X*, no current flows through the line wire *A*; hence phase winding *A* carries no current. Phase windings *B* and *C*, however, carry 1.73 times normal load. In diagram *Y*, a delta-connected motor operating under the same conditions will have normal current in the phase windings *AB* and *AC*, but twice normal current in the phase winding *BC*. These facts are also shown in the data given in the accompanying table.



Test Data Showing Effect of Single-Phase Operation on a Three-Phase Motor

Line Voltage			Line Current			Phase Current			Speed R.P.M.	Average Line			Induct'n Motor	Torque
AB	BC	CA	A	B	C	AB	BC	CA		I	Watts	P. F.	Output Watts	lb.-ft.
219.5	219.5	219.5	39.7	38.8	40.6	22.5	22.4	23.3	1,746	39.7	13,500	89.5	11,920	48.1
189.0	220.0	208.0	0	36.5	36.5	25.4	48.0	25.2	1,738	73.0	14,700	91.6	11,870	48.1
203.0	219.5	208.0	0	39.9	39.9	14.0	26.0	14.2	1,763	39.9	6,650	76.0	5,403	21.6
198.0	219.5	208.0	0	49.7	49.7	17.3	32.6	17.6	1,755	49.7	9,200	84.3	7,669	30.7
206.0	220.0	208.0	0	34.7	34.7	12.0	22.7	12.7	1,768	24.7	4,950	64.8	4,019	16.0

winding current. The corresponding heating is 1.33 times normal in the active phase. Hence fuses which just carry normal current and no more do not fully protect the delta-connected motor against overload due to single-phase operation. We may have a 16 per cent overload in one phase with only normal current over the line.

These facts are borne out experimentally by the data given in the accompanying table. These data were taken on a delta-connected motor, which had special leads brought out from the windings so that current readings could be taken in the phase windings as well as in the lines supplying the motor. The first line of the table gives the relation existing between the line voltages, line currents, and phase currents, when the motor is under normal operation. As will be noticed the three line voltages, *AB*, *BC* and *CA* (these letters are same as in diagram *Y*) are equal and the currents in the three lines are approximately equal. This is also true of the phase currents; that is, the currents in the phase windings (legs of the delta) are approximately equal. In the next four lines of the table the relations are shown that exist when the current through the *A* line wire is interrupted. As can be seen the motor maintains the voltages between the lines *A* and *B* (*AB* in table). The motor load in watts and in lb-ft. torque is given in the last two columns of the table.

In line 2 of the table the motor is carrying full load torque. The line current is a little more than 1.73 times normal. The currents in windings *AB* and *CA* are nearly normal. But the current in *BC* is twice normal.

In line 3 of the table the torque is reduced until the motor is drawing full load line current. This load would not operate any fuses or overload relays rated at full-load motor line current. Yet the current in winding *BC* is more than 16 per cent above normal.

Line 4 of the table shows an intermediate load between lines 2 and 3. Line 5 shows the load which gives normal current in winding *BC*. This is the maximum load with which the motor can operate single phase without carrying an overload. But notice that this draws less than normal line current.

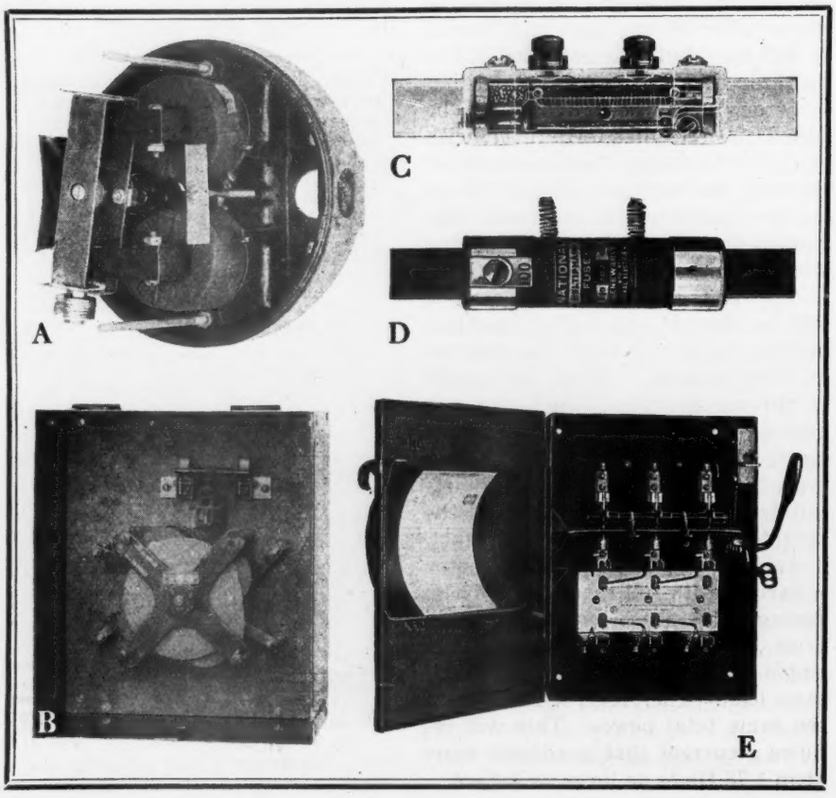
For a two-phase induction motor operating single phase the current in the active phase is double the value with the same load under normal two-phase operation. Overload protection should protect this motor from damage.

How can we protect a motor against damage due to single-phase operation?

(1) Do not over-fuse. However, our fuses must be heavy enough to take care of momentary overloads. If we could set our fuses to blow with *any* excess over full-load current, a star-connected motor would be fully protected. A delta-connected motor would still have 16 per cent excess current in one winding. But

These devices were especially designed to protect against single phase operation of polyphase motors regardless of the amount of load carried.

There are some applications where it is necessary to protect against single phasing for reasons other than overload. For instance, in some machines, weaving certain kinds of cloth, it has been found that the difference in speed between three phase and single phase is sufficient to cause a difference in the texture of the material. The devices shown below are intended to shut down the motors whenever single phasing occurs, no matter what load is on the motor. At *A* is shown a phase-failure and phase-reverse relay made by the Cutler-Hammer Mfg. Company of Milwaukee, Wis. This relay is intended to give protection to equipment in case of phase-failure while running, of phase-reversal, or in case of a dead phase when starting. At *B* is shown the open-phase and phase-reversal relay made by the General Electric Company. It is said that this relay will not trip on balanced overloads but will trip on unbalanced overloads, such as caused by single phasing, or on phase reversal. At *C* is shown a multiphase, time-limit renewable fuse made by the Federal Electric Company of Chicago, Ill. This has a powder-packed, time-limit, renewable fuse in which is placed a small heat coil, the terminals of which are on the side of the fuse. These auxiliary terminals are connected to the line and load ends of an adjacent fuse. In case the adjacent fuse is blown, the open-phase voltage across the blown fuse is impressed on the heat elements of the first fuse. The heat element melts the fuse and then melts itself, thus making two breaks in the circuit and shutting down the motor. Likewise, the remaining fuse is blown if the motor is three phase. The 'extra connections' required by this fuse may be made by external wiring, or by the use of a special fuse block as is shown in the safety switch at *E*. In this case, a back-connected, auxiliary contact fuse is used, as shown at *D*.



we do not usually fuse as closely and accurately as this.

(2) Use protective devices that open all three lines together. Most compensators have overload trips that do this. Many across-the-line starters for small motors do not, but some give such protection.

If we have thermal relays for protection, it is possible to set them for exactly full load, for they provide plenty of time interval for permissible overloads.

These really protect a star-connected motor from damage due to single-phase operation, and permit only the 16 per cent excess current in a delta-connected motor. This amount of current is not sufficient to damage the motor provided the motor were not exposed to excessive external heat. But they must be properly installed and adjusted.

(3) There are relays on the market designed specifically to protect a motor from single-phase operation. These are additional devices and do not protect against overload.

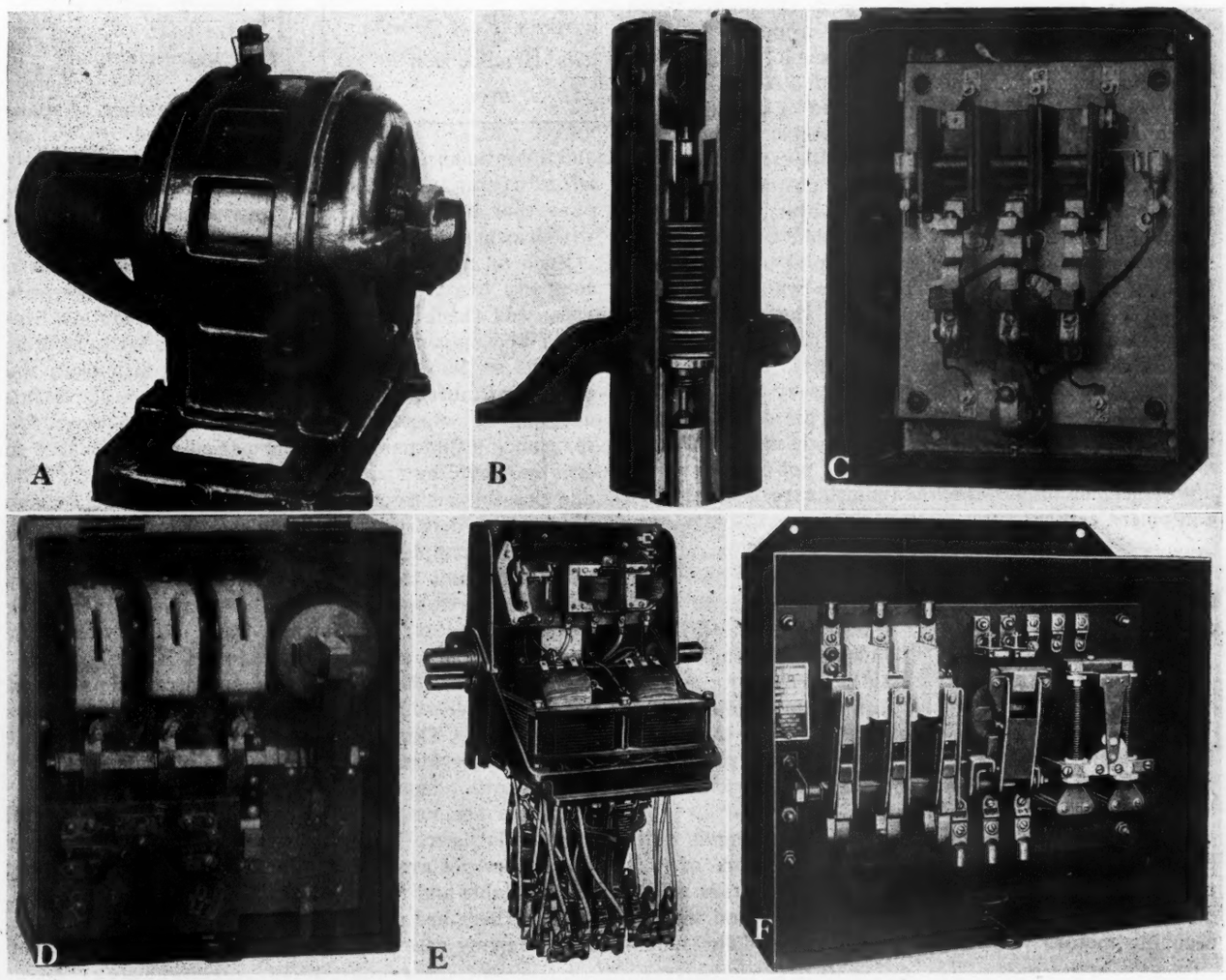
(4) There is also a simple fuse combination on the market that is so arranged that in case one fuse of a set of three fuses blows, another one of the three will immediately blow, thus shutting down the motor. This device thus protects against both overload and single-phase operation.

(5) There is also a thermal relay which can be attached to the motor and in contact with the stator laminations. This relay is said to function directly from the heat of the motor and therefore is claimed to protect the motor from overloads by single phasing or otherwise.

(*Please turn to page 207*)

Thermal relays depend upon the heat developed by the motor line current for operating their tripping mechanism.

In consequence, a time delay in tripping is obtained which is based upon the amount of overload current doing the heating and upon the time required for the thermal elements to be heated by this current. At *A*, the Type TR thermal relay made by the Automatic Reclosing Circuit Breaker Co., of Columbus, Ohio, is shown mounted on the frame of a motor. At the bottom of the sectional view of the relay shown in *B* is a liquid-filled bulb, which rests against the stator laminations. Excessive heat from the stator laminations volatilizes the liquid, which causes the copper bellows above the bulb to rise and operate the switch at the top of the relay. This device is said to protect against both overloading and single phasing inasmuch as it functions directly from the heat developed in the motor. *C* is an across-the-line starter, made by The Rowan Controller Co., of Baltimore, Md. Inside of the flashguards and directly over the blowout coils is a bimetallic strip which is acted upon by the heat developed by the motor line current in the blowout coils. Overloading of the motor causes this thermal relay to open the starter, thus stopping the motor. In the lower left-hand corner of *D* is shown the thermal relay used by the General Electric Co., in its across-the-line starter. Two heating elements connected in separate phases transmit to two thermostatic strips a heating effect that is in proportion to the load current passing through the heating elements. Load currents above normal cause the thermostatic strips to deflect and trip the motor off the line. *E* is a compensator made by the Electric Controller & Mfg. Co., of Cleveland, Ohio. An expansion wire located at the top of the compensator is used to provide overload and single-phase protection. This wire expands under the heat developed in it by the load current. *F* is the Thermaload starter made by the Monitor Controller Co., of Baltimore, Md. At the extreme right is shown the thermal relay which is used for protection against single phasing and overloads. Line current from two phases is carried through two thermal elements. Each of these elements is enclosed in an expansion tube which absorbs the heat generated in its unit. Line current greater than normal generates sufficient heat to cause the expansion tube to expand until a control contact is broken, thus stopping the motor.



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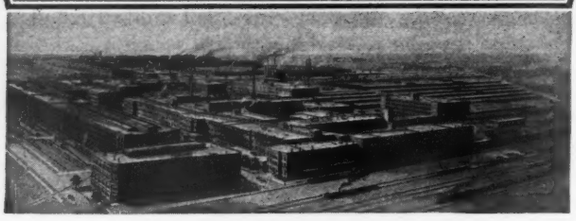


DANIEL H. BRAYMER
Editorial Director

Assisted by
G. A. VAN BRUNT F. E. GOODING A. J. WHITCOMB

Chicago, April, 1925

Plans Are Not Finished Until Results Are Known

IN PLANNING changes or alterations in production conditions, it frequently happens that the proposed change is not investigated thoroughly from the standpoint of all of the effects which may be produced if the change is adopted. One of the points which is frequently neglected is carrying through a full and complete investigation of the equipment which would be available for the service proposed. A striking example of this was in the construction of a building in which it had been planned to use a number of industrial electric trucks and tractors. The building plan, as originally laid out, was such that this equipment could have operated satisfactorily. However, during the period of construction, it was decided to change the plan somewhat and build a long ramp at a steep grade. Later, when manufacturers of trucks were called upon for an estimate, it was found that the grade of the ramp was steeper than trucks can ordinarily operate on. At that late time, it was impossible to change the building construction, so it was necessary to persuade a manufacturer to make alterations in his design to take care of this extra duty. Usually such makeshifts are not only not satisfactory, but they do not operate at the high efficiency under which standard, carefully-designed equipment can operate.

Full Voltage Starting of Larger Motors

THERE seems to be no question that all induction motor windings can be satisfactorily braced to stand the mechanical effect of full voltage starting, is the conclusion reached by J. L. Rylander in a paper read before the mid-winter convention of the American Institute of Electrical Engineers.

At the present time across-the-line starting is quite common on motors up to 15 hp. Extension of this method of starting to the larger sizes of motors means more to the industrial user, however, than merely securing motors with better coil bracings. The industrial motor operator must consider the strength of the machine driven by the motor, the character of the starting cycle required by this machine, whether the high-inertia starting load of the machine will result in belts slipping during starting thereby burning the belting, whether backlash in the gearing is going to result in broken gears, and whether excessive stresses will be put on other mechanical forms of power transmission between the motors and the machines driven by them.

He must also consider the effect of larger starting current on the feeders and whether or not this larger current is going to affect seriously the voltage regulation of these feeders. If he is a user of central station power he must consider the attitude of the central station toward drawing momentary heavy starting currents from their lines.

Full-voltage starting of squirrel-cage induction motors will greatly simplify the control equipment required and the attendance needed during starting of motors at the beginning of a run, or after a power failure. However, before putting in this type of control and the motor required with it on the larger drive units in the plant, careful consideration should be given to *all* of the factors involved, to make sure that the application is correct from both operating and maintenance standpoints.

Spare Part Stocks as Breakdown Insurance

EVERY now and then we hear an executive in an industrial plant say something to the effect that his inventory of spare parts required for repair and maintenance work is too high, and that he can't afford to pay interest on such a lot of capital for supplies that lie idle until emergency causes them to be withdrawn from the storerooms.

Such an argument is very similar to the one that a company can afford to carry its own fire insurance risks. If the building construction is absolutely fireproof and no combustible material is housed in it, that may be so, but this is far from the conditions in the average manufacturing establishment and one good fire can quickly wipe out enough investment to cover fire insurance premiums for a long period of time. Just so it is in providing spare parts for natural wear and tear and possible emergencies that will stop production and disarrange department schedules. Here we have a practical example of that familiar jingle, "For the want of a nail the shoe was lost; for the want of a shoe the horse was lost; for the want of a horse the general was lost; and for the want of a general, the battle was lost—all for the want of a horseshoe nail."

Suppose $50,000 is invested in spare repair parts and that the interest and carrying charges run as high as 15 per cent. This will represent $7,500 a year as the cost of repair insurance. Unless the plant is in a large city close to adequate stocks of materials, who can say that two serious breakdowns might not cost several times this figure in a single year if the needed repair parts were not available? Then, too, when these stocks are available and repairs are made while they are small, so that there are no serious and expensive breakdowns, in how many cases is credit given to the foresight and

good judgment of those in charge of repairs and maintenance for the wise and intelligent use of this investment, which on the books of the company appears to be a useless investment that might very well be done away with?

An accurate answer to this question will in most instances show a total ignorance of the possible savings that an experienced maintenance man can work out, and indicate that in too many cases his salary is based upon the number of hours he works and not on the actual earnings that he can show when $50,000 worth of spare parts and units are at his command to use when and where needed in a medium-sized works. The problem in inventory of these spare parts is not the total money they represent, but how effectively they are used in a definite program of continuous repair and maintenance work to keep up with natural wear and tear and forestall possible breakdowns. Adequate spare parts are just as essential as adequate stocks of raw materials, because the consumption of raw materials in and through machines has a definite bearing on the consumption of repair parts. No human being has yet found the way to eliminate natural wear and tear on rotating or reciprocating parts under constant or excessive loads, be these parts in mechanical or electrical machinery.

Give the Code a Chance to Answer Your Questions

IN VIEW of the questions relating to the installation of electrical equipment which are sometimes asked by practical men, there is reason for wondering if these men are as familiar as they should be with the requirements of the National Electrical Code. Anyone who has to do with the installation of wiring or equipment and does not make constant use of this little book is overlooking a very good source of information.

It should hardly be necessary to say that the Code, as it is familiarly called, is the boiled-down essence of safe practice. The regulations which it sets forth are the results of many years of experience with electrical installations of every character, viewed from every angle. As a reference work, it contains the answer to practically any question that may come up in the installation of any kind of power equipment that is driven by, or makes other use of, electrical energy.

In these statements there is no intention to imply that the Code is a perfect and finished work. The fact that it is revised from time to time, to meet new conditions or needs, shows that it is, however, a live document—not a set of obsolete regulations, perhaps good in theory but unworkable in practice. You may not see the reason for some of the requirements, and you may not agree with them. Regardless of the merits of this situation, you can not go wrong in obeying them. Otherwise, there is always the very good chance that mistakes which are costly in both time and money, will be made.

If you do not have a copy of the Code, get one and become thoroughly familiar with the subjects covered. Therein you will find the answers to many a puzzling question as to what is the required practice and safe procedure under given conditions.

Should the Entire Motor or Only a Part Be Changed?

ARE we justified in changing complete motors rather than armatures or field coils, as the case may be, when motors fail in steel mill service, was the question discussed by A. C. Cummings, Superintendent of Electrical Department, Carnegie Steel Company, Duquesne, Pa., before a recent meeting of the Association of Iron & Steel Electrical Engineers. He directed attention to the following points in favor of this practice:

(1) The repair shop personnel is usually a higher-paid and more intelligent class of men than those occupying mill maintenance positions. They, therefore, have more interest in making a thorough job of repairs than the mill men.

(2) Repairs made in the field, with a piece of apparatus shut down, are always made under rush conditions, and the care necessary to make a thoroughly workman-like job in every particular cannot be exercised when the men are being rushed to get the equipment going as soon as possible.

(3) Armatures and field coils stored around the mill to be installed in the motors in case of failure, usually are damaged in handling before they are actually installed for service, and for this reason do not perform as well as anticipated. If the complete motor is repaired and assembled in the shop and sent out on the job as a unit, there is little likelihood of damage due to careless handling.

It was pointed out that in most cases a complete motor can be substituted without an increase in the time lost in making the change, or in the amount of money invested in spare parts. Even if there were an increase in the amount of money so invested, it would be more than offset by the decrease in delays and maintenance cost. On the other hand, if this practice is to be followed, it is very important that facilities be provided to do this work with as much convenience and dispatch as possible. During the past several years there has been a tendency toward increasing size and capacity of mill machinery and mill parts, with a corresponding tendency toward an increase in the size of motor equipment used. The average motor size, therefore, is gradually increasing. This is particularly true of motors used on overhead travelling cranes.

While the discussion of this question is based on a background of steel mill experience, still the practice is worthy of consideration in any industry where it is necessary to keep power service interruptions to a minimum.

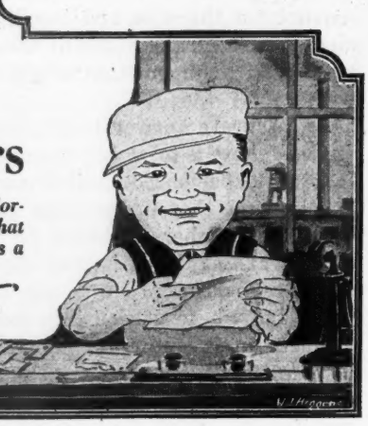
In the last analysis the question must be decided on the local conditions in your own plant. Factors that should be considered are: Number of types and sizes of motors in the plant (in the older plants, providing complete spare motors for the very old motors may be a serious factor); additional facilities that might be required for changing the larger motors with dispatch; possible decreased cost of shop repairs as compared to field repairs, together with the probability of longer life; the possibility of using less skilled men for changing complete motors than is required for changing parts of a motor; and the satisfaction of knowing that when a complete motor is substituted it will be in first-class condition, as compared to the chance that only a part of the motor will be in first-class condition when only a part of it has been changed.

This bet should not be overlooked, if reduction of your motor maintenance cost is one of your worries.

Questions Asked and Answered by Readers

Here is a place where you can get some inside information when you get stuck. The only restriction is that you do a good turn to the other fellow when he asks a question that you can answer from your experience.

Practical Pete



Who Can Answer These?

Cost of Changing Two-Phase Motors to Three-phase—The local power company is planning on changing its system from two phase to three phase. This will involve a corresponding change in a large number of motors ranging from 5 hp. to 50 hp. I should like to know if there will be any loss of efficiency in the motors as the result of this change. Also, please tell me the general procedure involved in changing motors from two phase to three phase, what troubles are likely to be encountered and about what the cost per motor or per horsepower will be.
Fort Smith, Ark. V. L. H.

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Connecting Commutator Leads of G. E. 25-Cycle Desk Fan Armatures—Will some reader please tell me the general layout of the coils and how the top and bottom leads are connected to the commutators of G. E., Type AOU, Form V2, 25-cycle desk fan armatures? I have rewound two different armatures without much success, for when the fan is connected across the line the armature rotates only very slowly, with the fan removed.
Phoenix, Ariz. F. R. S.

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Connecting Lineshaft Directly to Motor—We wish to connect a lineshaft approximately 100 ft. long directly to a 50-hp., 870-r.p.m. motor. The lineshaft can if necessary be supported from the ceiling, but we should prefer to mount it on top or at the side of heavy wooden or concrete posts. This department is on the ground floor and there is no basement underneath the building. I should like to know (1) if it is practicable to drive a lineshaft at this speed. (2) Would it be better to support the lineshaft on the top, or at the sides of the posts? (3) Is there likely to be excessive vibration? If so, how can it be overcome? (4) What kind of bearings should we use? Your advice will be greatly appreciated.
St. Louis, Mo. B. G. S.

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How Can This Motor Be Kept From Humming?—Can someone tell me how I can eliminate the magnetic hum of a 30-hp., shunt-wound, four-pole, 400-1,000-r.p.m. interpole motor? This hum is so loud that it can be heard all over a large department store. The following remedies have been tried: (1) Laminated pole shoes supplied with motor were changed for similar shoes of sturdier construction. The laminations in the new shoes were put together under pressure, riveted with bakelite varnish between them and baked. This did not stop the noise. (2) The air gap was increased. This helped somewhat, but caused circuit breaker to open. (3) Cast pole shoes were used, with no noticeable effect. (4) Skewed laminated pole shoes were tried, with no better results. (5) Used pole pieces with wider air gaps on tips. No results. (6) Magnetic wedges were used in armature slots. These helped somewhat. (7) Disconnecting interpoles had no effect. Before the magnetic wedges were tried, if full field strength was applied and the armature turned slowly by hand, with the brushes lifted up, it had a tendency to lock at several points. If rotated faster it would growl. Magnetic wedges almost removed this effect. Two wedges per slot were used, each 1/16 in. thick and insulated from each other. All armature connections are OK.
New York, N. Y. W. L. S.

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Rewinding Armature Increased Speed—I recently rewound the armature of a 100-hp., four-pole, shunt-wound, Northern motor and wish someone would tell me what is the matter with it. This armature had 110 bars and 55 slots and was wave-wound, with one dead coil and one half-idle bar. The coil pitch was 1-and-13 and the commutator pitch 1-and-56. When we rewound it one bar was taken out, which left 109 bars and one dead coil. I am not sure whether the commutator pitch was 1-and-56 or 1-and-55. When the armature was put back in the motor it ran at about 1,600 r.p.m., the commutator got hot and the bands threw solder, although the controller was on only the third point. I examined the field connections and took the voltage drop across each field coil; everything tested out OK. As a further check, a spare armature was put in this motor, and ran perfectly. Any suggestions you can give will be very welcome.
Wisconsin Rapids, Wis. W. B. L.

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When Should an Armature Be Scrapped Instead of Repaired?—I shall appreciate it if readers will give me their opinion on the following: If an armature needs new coils, a new commutator and a new shaft, especially if it is of the type that has the laminations stacked on the shaft, is a repair job, with only the laminations for a base, a profitable undertaking? Also, when should the core be junked and new laminations used?
Chicago, Ill. J. E. K.

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Replacing Motors When Trouble Develops—When armature or other troubles develop in a motor, should a new armature be put in or other repairs made, right on the job? Or is it better to replace the entire motor with a spare and send the damaged motor to the repair shop? This question has come up several times in our plant and I should like to know the practice followed by other readers.
Pittsburgh, Pa. E. W. D.

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Method of Restacking Transformer Core Laminations—When we restack transformer core laminations we often experience trouble in getting all of the iron back in place so that the cores will fit in the cases. We have followed the practice of burning paper underneath the cores after the laminations have been stacked. I should like to know (1) if this is good practice. (2) Is there any danger of removing the insulating varnish from between the laminations, thereby causing the cores to heat?
Chicago, Ill. G. C. C.

Answers Received To Questions Asked

Reclaiming Leather Belting—I should like to know if any readers have made an investigation to determine how much belting must be in use before it will pay a plant to undertake belt reclamation work. I should also like to know the amount and kind of equipment required to do such work and about what savings we could expect to make. I shall appreciate any suggestions or information you can give me.
Cleveland, Ohio. E. E. L.

Replying to E. E. L.'s question in the February issue on reclaiming leather belting, we would say that if we understand your question what you want to know is how large a plant you must have or how much belting in use before it pays to set up an equipment for reclaiming, that is, degreasing, lapping, re-gluing, etc. The answer to this will pretty obviously depend upon the nature of the drives; in other words, upon how quickly belts are deteriorated due to the nature of service to which they are subjected.

Where there is a great deal of oil or dirt around, it probably would pay to reclaim belts in a plant where there was less belting in use than in a larger and cleaner plant where the conditions were more ideal. A gasoline tank of sufficient size to hold the belts in loose rolls would be required, with proper safeguards for fire hazard, and preferably the work should be done out of doors or in a shed distant from other buildings of importance. There should be a dry, airy shed out of the buildings where the belts can be allowed to dry, that is, the gasoline to evaporate, and, of course, the size of this will depend entirely upon the amount of work done. In the summer time it can ordinarily be done outdoors; possibly in a garage or some such place which is open and not closed up tightly.

After the leather is degreased, it will have to be re-lapped. A good set of belt tools, including a small lapping machine, such as the Prims Machine made by J. C. Prims, Hornell, N. Y., should be installed. A man who understands the cutting of laps, gluing, cement, etc., will be required, and then a small treating tank, in which the belts could be treated in a proper belt preserver.

Where belts receive a good deal of abuse, an appreciable saving probably could be made, and in large plants it

would be quite a large item. It all hinges upon whether there is enough work to justify the time of a man, as the investment in equipment is only small.

Of course, a small press would be required but a hand press would ordinarily be sufficient. Probably in most small plants, it would be cheaper to send such belts to a belt manufacturer and let him do it.

J. EDGAR RHOADS.
J. E. Rhoads & Sons,
Philadelphia, Pa.

* * * *

How to Determine Amount of Plugging Resistance to Use—I would like to know the right way to figure the amount of resistance used for starting series motors that are plugged, such as on blooming-mill, roll-table motors, crane-trolley motors, or any motor that is subjected to plugging service. I would also like to know how to figure the resistance used in the secondary circuit of slip-ring motors driving fans.
Mingo Junction, Ohio. E. E. S.

Replying to the question by E. E. S. in the January issue, if a motor does not start from rest, but is plugged, the maximum voltage across the armature and its accelerating resistor is the sum of the line voltage and the counter-voltage developed by the motor at the instant of reversal. In order to limit the current with these combined voltages a plugging resistor is required. The proper value of this resistor can be determined by dividing the counter voltage of the motor at the instant of reversal by the allowable current inrush. This value can be discounted by 10 or 15 per cent to allow for resistance and reactance of leads and loss of speed at the instant of plugging. This resistance should usually be added as a single step.

In order to calculate the balanced three-phase secondary resistance necessary for a wound-rotor induction motor, the locked rotor volts, and the full-load secondary current must be known. When the locked rotor voltage is known the full-load secondary current can be found by the formula: Full-load secondary current equals hp. times 746 divided by the locked secondary volts times 1.73 times (1 minus the slip).

The Y-connected, balanced three-phase secondary resistance can be found by the following formula: Resistance per leg of the Y, in ohms, equals the locked secondary volts divided by 1.73 times the full-load secondary current times (100 divided by the torque developed on the first point of controller or contactor, expressed in per cent of full-load torque minus 0.10).

The secondary resistance for wound-rotor motors is usually connected in Y. There are cases where it is desired to reduce the current handled by the controller fingers; in such cases the resistor is connected delta. If the resistors are delta-connected, determine the proper value of Y-connected resistance and multiply by three to get the proper resistance of each leg of the delta. The current in each leg of the delta-connected resistors is the motor secondary current divided by 1.73.

MARTIN G. LANE.
Asst. Chief Electrician,
Superior Mines, Union Pacific Coal Co.,
Superior, Wyo.

Throwing Large Squirrel-Cage Motors Across the Line—Will someone who has had experience with starting large squirrel-cage motors (50 hp. and larger) by throwing them directly across the line, please report their results? Has such practice injured the motors in any way? Has it resulted in any damage to the machinery driven? Has it interfered with the supply of current to other motors in the same plant?
Indianapolis, Ind. D. W. T.

In answer to D. W. T.'s question in the January issue, I should like to say that this is common practice in the coal industry where a. c. mining machines are used. These machines usually run from 35 to 50 hp. The stators on these machines are connected through controllers arranged for star or delta connections.

This system is very successful and does not cause any damage to the machines nor does it have any bad effects on the voltage or other motors, outside of a slight surge.

We have also on several occasions had to start a 200-kw. motor-generator set by throwing it across the line.

This is very risky both to machine and operator and I would not advise doing it except in extreme emergencies, and then the oil switch would have to be thrown in and out very rapidly until the machine is brought up to half-speed, when it can be left in without danger.

H. BANHOLZER.
Electrical and Mechanical Engineer,
Knox Consolidated Coal Co.,
Bicknell, Ind.

* * * *

In reply to D. W. T. in the January issue, throwing large squirrel-cage motors across the line is becoming regular practice, particularly for motors driving power station auxiliary equipment, as it obviates freezing of contacts and allied troubles in starting compensators, due to the inherently small rupturing capacity of such equipment during the starting period.

Motor manufacturers are designing equipment for this service and no serious trouble will occur if the service or duty of the motor is understood before installation. Troubles have occurred with motors due to lack of proper reinforcement at the ends of the stator coils, but so far as the writer knows these have been limited to the motors of one manufacturer and were rectified after installation.

The question of damage to the machinery driven must be settled by the manufacturer of the driven machine. In cases where the motor is direct-connected through gearing, there may be a possibility of damage but in every case that has come under the writer's observation, the machine manufacturer was agreeable to this method of starting and no damage has as yet been reported. Coal crushing equipment, in particular, must be carefully investigated when this method of starting is under consideration.

The question of the effect of this method of starting on the current supply to other motors in the same plant cannot be answered directly. In power station practice the capacity of the motor being started is usually so small in comparison to the generating equipment that no marked fluctuations of voltage are caused. However, in one case where a 150-hp. motor was being started with a 1,250-kva. generator supplying it, the generator being partly loaded, a marked momentary fluctuation was noticeable. This, however, is an operating feature that can be avoided.

In general, the motor manufacturer should know that the motor is to be started in this manner so that no older type of equipment with insufficient end winding reinforcement will be furnished for this duty.

C. OTTO VON DANNENBERG.
The J. G. White Engineering Corp.,
New York, N. Y.

* * * *

In reply to D. W. T. in the January issue, it is not common practice to start squirrel-cage motors of 50 hp. and larger on full voltage. Consequently, motors of this size are not as a rule designed for this sort of operation. It is true that motors may stand a certain amount of full-voltage starting, but the best procedure is to write the motor manufacturer, giving the full rating of the motor, together with the serial number. Also advise the probable number of times the motors will start on full voltage, as well as the kinds of machines the motors have to drive. With this information the motor manufacturer will be in a position to give authentic information as to whether or not his motors can be used in this way. If such method of starting is contemplated before the motor is purchased, it is always possible to have the motor coils equipped with special bracing, which will insure against any possible coil distortion due to full-voltage starting.

Probably the majority of general-purpose, squirrel-cage type motors, 110-volt, 220-volt, 440-volt or 550-volt, 50-hp. and larger, as manufactured by reputable manufacturers, will stand a certain amount of starting on full voltage without injury. Continuous operation with this method of starting is likely to cause trouble in time, unless the motor coils have first received special treatment which will enable them to resist the strains caused by the high current which exists at the time of starting. If the motors are 2,200 volts, the windings are of comparatively small cross-section, due to the small, full-load current. Such motors are more susceptible to distortion of their windings than other motors, due to the windings having less mechanical strength.

If D. W. T. tries starting his motors on full voltage, he should watch for trouble at the point where the stator coils leave the iron stacking. Any distortion of the coils or loosening of the coils at this point may cause abrasion of the insulation where the coil bends around the iron, and in time will cause a ground. This tendency of coils to loosen is not mainly due to the mechanical shock which occurs when the motor starts, but is due to high magnetic stresses due, in turn, to the high currents which exist in the stator windings at the time of starting. A squirrel-cage motor draws several times its full-load current at the instant of starting, which value gradually tapers off to full-load value as the motor comes up to speed. The mechanical shock to the motor starting

on full voltage is not so great as might be supposed, particularly if the load has a high frictional value, such as starting a bucket conveyor or a plunger pump. Referring to Fig. 1, curve *B* is the curve of a conveyor which starts cold after the lubrication has settled down. A torque equal to *Y* is necessary to break the static friction, which falls off to a value *Q*, after the conveyor is up to speed and all the bearing surfaces are lubricated and warmed up. The characteristic torque curve of a squirrel-cage motor is given by *C*. It will be noted that the difference between *U* (torque exerted by motor at starting) is not excessive as compared with the torque demanded by the load at starting. However, the starting current corresponding to curve *C* may be five or six times the full-load current of the motor and it is the high magnetic stresses resulting from this current which may cause the distortion of the motor windings. Curve *D* shows the motor torque curve when started by a compensator. It is evident that this is insufficient for starting up the load represented by curve *B*, although it would have the advantage of taking any back-lash out of the gearing, thus saving some mechanical jar when the motor was finally thrown on full voltage.

If the motor in question is connected by belt to a machine having very high inertia, as for example, a shear having a flywheel, the starting torque exerted by the motor may be so great as to make the belt slip, causing burned spots on the belt. D. W. T. does not state definitely that his motors are general-purpose, squirrel-cage machines, but if they are high-torque motors with high-resistance rotors, the starting torque characteristics of each motor will be similar to curve *E*. The difference between the starting torque of such a motor and curve *B* is represented by the difference between *W* and *Y*, which is considerably greater than the difference between *U* and *Y*. The attendant shock on the driven machinery with such a motor is greater, but the likelihood of trouble with the motor itself is less even though the mechanical shock is much greater. This is due to the fact that the high-resistance rotor windings reduce the inrush of current with attendant magnetic stresses, which reduces the chance of any distortion of the motor windings by just that amount. In all cases of full-voltage starting, it is important that there be no great amount of back-lash in the gearing; otherwise too great a starting torque might break the teeth of the gears.

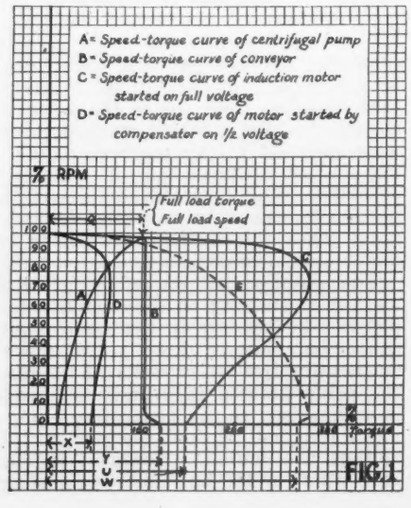
The question of the amount of current drawn from the line is often a relative one. A case came to the writer's attention recently where the operator was worried about the probable starting current drawn from the line by a 40-hp. motor started on full voltage when a 350-hp. motor which was connected to the same mains had a full-load current practically the same as the locked rotor current of the 40-hp. motor. In other words, the 40-hp. motor would have a momentary current inrush hardly any greater than the full-load current of the large motor, and considerably less than the inrush current of the large motor when starting. Some power companies specify in their rules that, "where an installation consists of a number of motors, the starting device may be omitted from any motor which, with the starting device omitted, would have a current less than the permissible maximum for the largest motor in the installation."

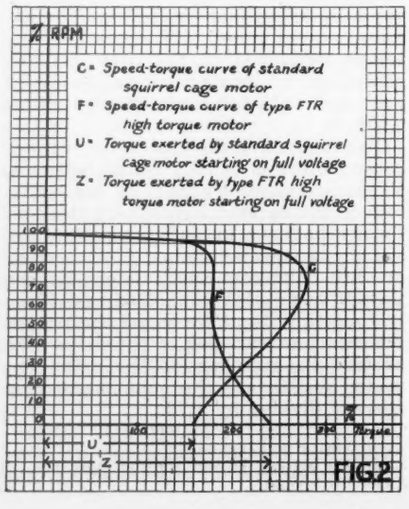
If the motor drives a fan having a speed-torque curve like *A* in Fig. 1, a compensator will give a motor characteristic curve *D*, which will permit a comparatively low starting current. However, if the load curve is similar to *B* it is doubtful if the increase in starting current due to the omission of the compensator will have any appreciable effects. For example, curve *C* shows that 150 per cent torque is exerted by the motor at full-voltage starting. The load curve *B* indicates 120 per cent torque is required. A compensator reducing the voltage to 90 per cent of full value reduces the starting torque to 81 per cent (starting torque is reduced according to the square of the applied voltage), or 121.5 per cent of full-load torque. This is barely enough to start the load and it would not be feasible to reduce the applied voltage any lower. The starting current is theoretically reduced to 81 per cent of its former value. As a matter of fact, there will probably be even a larger reduction due to losses in the compensator and unbalanced voltages. Consequently, the addition of approximately 15 per cent more current should not result in any bad effect, providing previous starting conditions were satisfactory and the power lines have a reasonable margin in capacity. Another point in favor of full-voltage starting is the fact that the increase in applied torque due to full-voltage starting means that much less time during which the higher current exists. Therefore, if D. W. T.'s load curve is similar to *B*, a compensator is of no particular advantage with a motor having the characteristics shown in *C*.

D. W. T. may also be interested to know that the current taken in starting by compensator is often much greater than any current that would ever be obtained when starting by the full-voltage method. The stator current ceases immediately when a motor is disconnected from the starting tap of a compensator preparatory to throwing the motor on full voltage. The rotor current, however, will continue to flow for a short period of time, due to the fact that the decrease in the flux tends to keep it flowing. This rotating flux generates a voltage in the stator, the frequency of which is somewhat different from the line frequency. If the compensator is thrown to the full-voltage position while this induced voltage in the stator still exists, it is possible that the induced voltage and the line voltage will be in phase opposition. This will cause a surge of current which will be several times as great as any current the motor can possibly draw from the line when started on full voltage from rest. This surge lasts for a fraction of a second, but it may have a worse effect on the motor and starting equipment than current obtained by full-voltage starting. Of course, if the compensator closes when the two voltages are in phase coincidence, there will be no undue rush of current.

The General Electric Company has a line of motors, type FTR, up to 100 hp., having high-starting torque, relatively low starting current, low slip and high efficiency, especially adapted for starting on full voltage. These are not general-purpose motors, but are designed for use with automatic refrigerating machines, automatic pumping installations, conveyors, reciprocating pumps—in fact, for all installations where high starting torque, low starting current and high all-day efficiency are desirable. Larger motors, type FT, can also be furnished with similar characteristics, except the starting torque is not as high as with the type FTR motors. Fig. 2 shows the speed-torque curve of an FTR motor compared with a standard squirrel-cage motor. Note the difference in starting torque. Also, the starting current cor-

Fig. 1—Speed-torque curves of certain types of loads and of standard squirrel-cage motors started on one-half voltage and full voltage. Fig. 2—Speed-torque curves of standard squirrel-cage motor and type FTR motor, started on full voltage.


A= Speed-torque curve of centrifugal pump
B= Speed-torque curve of conveyor
C= Speed-torque curve of induction motor started on full voltage
D= Speed-torque curve of motor started by compensator on ½ voltage
% RPM
Full load torque
Full load speed
% Torque
FIG.1


% RPM
C= Speed-torque curve of standard squirrel cage motor
F= Speed-torque curve of type FTR high torque motor
U= Torque exerted by standard squirrel cage motor starting on full voltage
Z= Torque exerted by type FTR high torque motor starting on full voltage
% Torque
FIG.2

responding to curve *A* is considerably less than the starting current corresponding to curve *B*, in Fig. 1.

R. F. EMERSON.
Industrial Engineering Dept.,
General Electric Co.,
Schenectady, N. Y.

* * * *

In reply to D. W. T.'s question in the January issue, throwing large squirrel-cage motors directly on the line is not usual practice and experience on this point may be lacking; so our experience, which is similar, may be useful.

We have a lineshaft driving beaters, pumps, and stuffchest agitators, the principal load being in the beaters, which, as the stock settles and thickens, have a very heavy starting torque and slow acceleration. This lineshaft was formerly driven by a steam engine but in the process of changing to individual motor drive it was desirable to replace the engine temporarily by a motor. The only motor available was a 125-hp., 14-pole, three-phase, 60-cycle, 440-volt, squirrel-cage motor with manually-operated compensator; so it was installed. This motor will not start on less than the 90 per cent voltage tap and sometimes even refuses to start, so that the belt has to be shaken to lessen the initial friction.

But, although the motor has been operating on this service for about 18 months, pending a decision as to a rearrangement of the machinery, it shows no sign of distress or weakness. The rated motor current at full load is 161 amp., but on starting it takes from 550 to 600 amp., and although the generator is rated at 1,250 kw., there is considerable flickering of the lights. As a rule, the motor takes 30 to 45 sec. to come up to a speed where the compensator can be thrown to the running position, at which time the current has fallen to 250 amp., but jumps temporarily to 400 amp., falling back to 130 to 150 amp., which is the average running load.

We have also a 200-hp. synchronous motor that was originally purchased to drive a Jordan engine, which has starting characteristics similar to a centrifugal pump. Ultimately, however, we found it more convenient to use the motor on a large breaker beater system. This motor will not start on the 90 per cent tap without the assistance of men pulling on the belt, although this condition will shortly be corrected by a change in the amortisseur windings. However, the motor starts up in good shape when the line voltage is raised to 550 volts. At this voltage the motor takes from 700 to 800 amp. in the feeder circuit and has been started in this way several times without injury.

On the other hand, in another power house we had a 100-hp., three-phase, 60-cycle, 2,300-volt, 16-pole, squirrel-cage motor driving a condenser extraction pump. The insulation of the motor was known to be in poor shape. One day in starting up in a hurry a new watch engineer pulled the compensator handle directly into the running position—the latch was afterwards found to be stuck—and grounded about a dozen coils with a report like a cannon.

In general, if the starting torque and inertia of the motor load are not too great to allow of its accelerating rapidly and building up a suitable counter-electromotive force before the very heavy current developed by the full impressed voltage can cause undue heating, the motor will not be damaged. But as the line must be fused to stand this current, the motor has little protection unless relays are used which can be short-circuited during the starting period.

The disturbances on the power system are a more serious matter, as with a comparatively small generator the voltage may be pulled down so that undervoltage releases on other circuits operate. We have had this occur with sticking contacts on the automatic starter of the synchronous motor, and even where the fluctuation is not so great it causes a very unpleasant flickering of the lights. For this reason, most public service companies in cities will not supply service where squirrel-cage motors of over 25 hp. are installed, even with compensators, for while the starting power may not be excessive, the large wattless current affects voltage regulation.

I hope that our experience may be of some use to D. W. T.

H. D. FISHER.
Plant Engineer,
New Haven Pulp & Board Company,
New Haven, Conn.

* * * *

Replying to the inquiry by D. W. T., in the January issue, it is quite feasible to start motors of 50 hp. rating or larger, directly off the line, and it is not as a rule liable to cause much damage especially if the motor is in good condition electrically. However, it is a method which should be avoided unless everything else has been tried and the emergency is serious enough to warrant the risk.

There are several points which should be considered regarding this method of starting. In the first place, the motor should be in good mechanical and electrical condition. The load should be of small inertia or should be connected through a clutch. If the load is connected through a mechanical, magnetic or air type of clutch, so that the motor can start freely with only its own inertia to overcome, the initial rush of current will not be much over two to three times normal and will be only momentary. Under these conditions the time required for the motor to start and reach approximately synchronous speed, would be very short. With a clutch connection the type of load matters very little as long as it is the load which the motor has customarily been driving. If the load is direct-connected, however, the nature of the load should be considered. If the load is of a light nature with small inertia, it will not seriously affect the starting, but if it is a stiff, heavy load of a kind which ordinarily gives the motor a hard struggle even when starting with a compensator, it is liable to cause trouble. The danger can be reduced somewhat by putting the drive into motion before starting. I will refer to this again later.

The size of main feeders and transformers should be looked into, but if the plant has a considerable number of motors of large size, the mains and transformers, switching equipment, etc., are sure to be more than safe, and there is little chance of interrupting service on the other motors. On the other hand if the plant has only three or four motors, there would be a good chance of knocking out the main breaker. In a case like this the overload relays on the main breaker might be blocked or set up high just long enough to start the motor, and then be released.

We have started a 300-hp. squirrel-cage induction motor directly off the line, successfully. The motor in question was driving one of our most important mill lines and we had the misfortune to burn out the auto-transformer. It was impossible for us to secure a spare or to get the other one repaired inside of two weeks, and on account of production conditions we had to get it running without the loss of one moment longer than was absolutely necessary. We decided, after a survey of conditions, that it was worth while taking a chance on starting it off the line. Fortunately the motor was connected to its load through a magnetic clutch and, therefore, could be started with only its own inertia to overcome.

To start it, we blocked the overload relays on the feeder switch at the main board and at the motor switch, wound a rope several times around the shaft, started the rotor turning over by hand and with several men pulling on the rope, brought the rotor up to a fair speed; then we pulled the rope clear and closed the switch. The motor started off nicely and with no evidence of distress. We then threw in the clutch and unblocked the relays. It was necessary for us to repeat this performance once more before the auto-transformer was fixed and it worked equally well the second time.

We have had occasion to start several motors of over 50 hp. rating in this manner and by observing the precautions outlined and having the rotor turning over in the proper direction at the moment the switch is closed, we have had no injury to the motors so started, no damage to machinery, and no interruptions of service to the other motors.

By having the rotor in motion when the current is applied, the initial rush of current is greatly reduced, so that it amounts to little more than that taken by a motor started from a dead stop, with the auto-transformer on the 70 per cent taps.

Our experience along this line, although successful, led us to finally purchase a spare auto-transformer large enough to handle any of our motors, and this we have mounted on a skid, easily transported to any place required. We would suggest this as advisable if much trouble is being had with auto-transformers and starting switches. A good oil switch could also be mounted on the skid with the transformer, and such an outfit could be quickly connected and the crippled apparatus repaired at leisure.

L. J. CLAYTON.
Asst. Mechanical Engineer,
The Goodyear Tire & Rubber Company
of Canada, Ltd., Bowmanville, Ont., Can.

Connecting Watt-hour Meter to Three-Wire Circuit—Will some reader please give me a diagram and explanation of how to connect a watt-hour meter to an Edison three-wire circuit? Is a special type of meter required? Why?
Bellaire, Ohio. J. R. B.

J. R. B. will find an answer to his question in the January issue in the accompanying diagram and explanation.

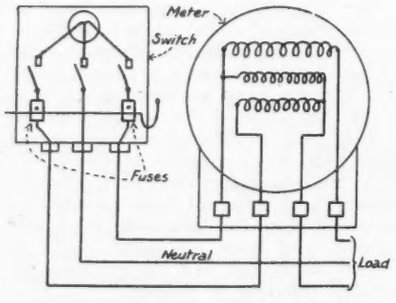
The diagram shows a three-wire meter (a meter made for the Edison three-wire system) connected to the Edison three-wire circuit. This is the connection used in conjunction with a meter loop. Note that the neutral wire does not pass through the meter, but passes through the service switch. Also the neutral is "solid"; that is, it is not fused. (See page 64, paragraph a, Article 8 of the National Electrical Code.) Since the neutral wire is grounded no fuse is needed. The neutral wire need not pass through the meter because all of the current must pass through the outside wires. This includes the unbalanced current in the neutral. Thus all the current is metered. The potential coil of the meter is connected across the outside wires.

When the service switch, service fuses and meter are combined in an approved device, having no live parts or exposed wiring, and which is capable of being sealed or locked, the switch may be so connected that it will not disconnect the fuses or meter from the supply line (page 18, Article 4, paragraph b of the National Electrical Code).

The connections for watt-hour meters are the same for both a. c. and d. c. meters in the Edison three-wire system. If the supply is a. c. an a. c. meter is used; if d. c. a d. c. meter is used.

A three-wire meter as shown in the diagram is required because, as before stated, there are two wires in which the current must be metered. If the regular single-phase a. c. or two-wire d. c. meter were used current would pass to the load and back to the supply without going through the meter for the reason that there is only one current coil in the meter. Assume, for instance, a three-wire d. c. system, feeding an unbalanced load, with most of the load between the positive and neutral, and a two-wire meter whose current coil is connected in the negative side of the system. The current would pass from positive to negative through the meter and back to its source. The unbalanced current would pass from positive to neutral through the load and return on the neutral without going through the current coil of the meter, which is in the negative side. If the meter is connected with its current coil in the positive side with the unbalanced load on the opposite side, most of the load being between neutral and negative, the current will flow out through the positive, thence through the meter and load and back to its source, through the negative wire.

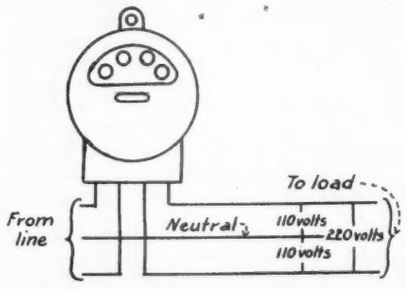
The unbalanced current will flow out through the neutral, through the load and return through the negative, and thus not go through the current coil of the meter, which is on the positive side. From the foregoing it is evident that such a meter could not be successfully used on three-wire circuits.
Concord, Mass. DONALD FERGUSON.



Internal and external connections of three-wire meter connected to Edison three-wire circuit.

* * * *

In answer to the question asked by J. R. B. in the January issue of INDUSTRIAL ENGINEER, as the fundamental principle of the watt-hour meter is the same as that of a motor it is no more possible to use a 110-volt motor under 220-volt pressure than it is to use a two-wire, 110-volt meter on a three-wire, 110-220-volt circuit, and for the same reasons. If you were to connect a two-wire, 110-volt meter to a three-wire, 110-220-volt circuit you would burn up and ruin the meter.

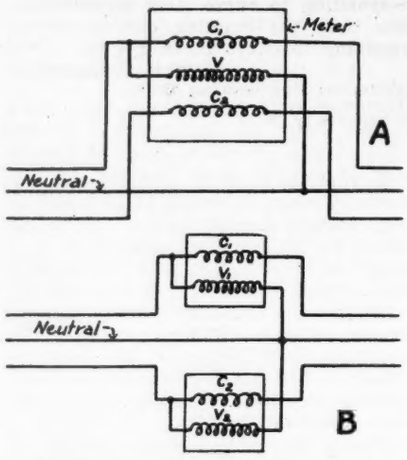


Three-wire watt-hour meter connected to Edison three-wire circuit.

The diagram shows the method of connecting the ordinary type of three-wire meter. The connection shown applies to circuits carrying from 1 to 100 amp. Current transformers must be used when the circuit exceeds 100 amp.
Inspector, EDWIN V. LAMBERT.
Philadelphia Fire Underwriters,
Ardsley, Pa.

* * * *

Replying to J. R. B.'s question in the January issue, in the accompanying diagram *A* shows the conventional method used by one company for measuring the energy used in a three-wire circuit. This method has the objection that if the voltage coil is connected to the line and the neutral, the voltage will be lower and the registration lower on the side carrying the greater load. When connected to the side with the lighter load, the voltage to neutral will rise and the registration will be higher than it should be. However, in the large three-wire distribution systems the unbalance is generally so small that the error in this method of connection is negligible.



Connections for measuring energy used in a three-wire circuit by means of, A, a single three-wire meter and, B, two two-wire meters.

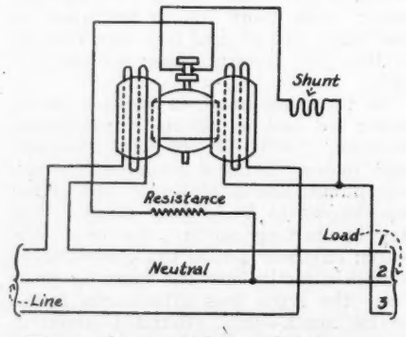
It is also possible to obtain a meter with a voltage coil connected between the outside legs, or a coil with double the voltage of the coil shown in *A*. This gives a registration approximating the average of the two voltages to neutral and has the advantage over the other types indicated in that there need be only four terminals, as against five in diagram *A*.

For absolutely accurate registration two, two-wire meters can be used, each connected with the current coil in the outside leg and the voltage coil to the neutral as shown in *B*. The three-wire meter is a standard type of meter and is not considered special.
C. OTTO VON DANNENBERG.
The J. G. White Engineering Corp.,
New York, N. Y.

* * * *

In reply to the question by J. R. B. in the January issue, he may use either two, two-wire instruments or one three-wire instrument. There is very little difference in the construction of the meters and the principle of operation is exactly the same. In meters designed for use on three-wire circuits the two series coils are distinct and the ends of each are brought out to terminals The diagram will illustrate the construction and connections of a three-wire watt-hour meter for an Edison system.

The voltage coils may be connected across lines *1* and *3*, *1* and *2* or *2* and *3*.



Three-wire watt-hour meter connected to Edison three-wire circuit.

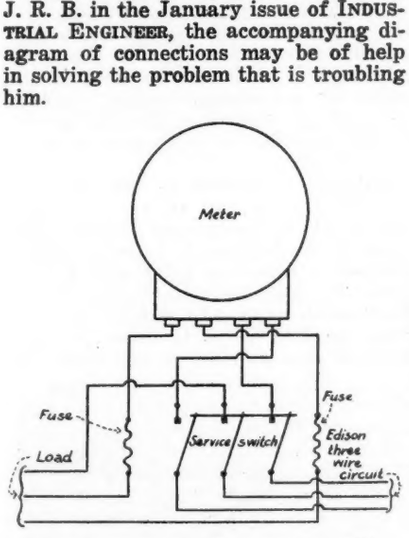
When the connection shown is used, the torque exerted on the armature is equal to the sum of the torques of coils *A* and *B*. On a well-balanced load the torques are equal and the meter will register accurately. On a badly unbalanced load, where the voltages will not be equal, the torques will not bear the same ratio to the load. On unbalanced loads the meter usually registers more power than is really used. Another important point to consider when connecting the meter to an unbalanced load is that the error is greater when the voltage coil is connected between an outside wire and the neutral.

If your circuits are subject to a serious unbalance, it would be well to use two, two-wire meters and take the sum of the readings of these two meters. This is the most accurate method in practice. Any reliable manufacturer of meters can furnish excellent meters of either kind and will be glad to give you any further information you may require. In case you are interested in meters of all kinds, Jansky's "Electrical Meters," published by McGraw-Hill Book Co., will give you any ordinary information you may wish.

Chief Electrician, LEE F. DANN.
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

Answering the question asked by J. R. B. in the January issue of INDUSTRIAL ENGINEER, the accompanying diagram of connections may be of help in solving the problem that is troubling him.



Watt-hour meter connected to Edison three-wire circuit for lighting service.

In explanation I will say that he made no mention as to the use of this meter in any particular circuit. The diagram shows the method of connecting a meter for regular lighting service on a 250-volt, three-wire circuit, carrying up to 30 amp.

NATHANIEL W. BLANCHARD.
Inwood, Long Island, N. Y.

* * * *

Using A. C. Generator as Synchronous Motor—What changes, if any, are necessary in order to use a stationary-field, revolving-armature, a.c. generator as a synchronous motor? This is a Westinghouse generator, rated at 25 kva., 480 volts, 30 amp., three-phase, 60 cycles, 1,800 r.p.m., serial No. 4212835. The exciter is direct-connected to the generator shaft and is rated at ¾ kw., 125 volts, 6 amp.

I should like to use this generator as a synchronous motor to drive a centrifugal sugar drier and to correct power factor. The power supply is 480 volts and all motors are rated 440 volts. If I can use this generator as planned, what horsepower will be developed and what will be the ampere input? Will I have to have an outside supply of direct current for excitation, or can I use the exciter on the machine?
Negros Occidental, P. I. A. C. M.

In answer to A. C. M.'s question in the February issue, these machines are built to serve either as generators or motors, but must have a squirrel-cage winding when used as synchronous motors, or the starting torque will be very low.

When used as a motor, the machine in question will develop approximately 35 hp., and the current taken will be about 30 amp. The direct-connected exciter on the machine is all that you will need for excitation purposes. However, unless the connected horsepower load is small, you will not realize much from this machine as regards power factor correction because its capacity is very limited by reason of the small excitation current available from the exciter. I would suggest that you try out a set of static condensers for power factor correction if the machine does not help you out enough. Any reliable electrical manufacturer, such as the General Electric Company, or the Westinghouse Electric & Mfg. Company will gladly give you any information you wish. LEE F. DANN.
Chief Electrician,
Donnacona Paper Co., Ltd.,
Donnacona, Que., Can.

* * * *

Determining Size of Conductors for Intermittent-Rated Motors—Will some reader of INDUSTRIAL ENGINEER please give a method of computing the sizes of rubber covered cables to be used for connecting intermittent-rated motors—particularly half-hour rated crane motors?
Montreal, Can. F. P.

In answer to the question by F. P. in a late issue, motor ratings for service of a periodic nature, or a continually recurring cycle of operations, can be calculated from the root-mean-square formula. This method is based on the fact that heating in a motor is proportional to the square of the load and the duration of the load.

Take a crane motor that develops 20 hp. for 5 sec., 30 hp. for 15 sec., 10 hp. for 15 sec., and 0 hp. for 25 sec.

Then:
$$20^2 \times 5 = 2{,}000$$
$$30^2 \times 15 = 13{,}500$$
$$10^2 \times 15 = 1{,}500$$
$$0^2 \times 25 = 0$$
$$17{,}000$$

The square root of 17,000 divided by 60 will give the approximate average horsepower required to complete the cycle, which in this case is 16.83 hp. In any event the cable should be large enough to safely carry the peak load of 30 hp. for 15 sec.

Goldfield, Nev. PHIL D. COMER.

* * * *

In a recent issue F. P. asked for information as to the proper method of computing the size of wire to be used in connecting up motors for intermittent duty, such as crane motors. This request came from Canada and I am not sure whether the rules of the National Board of Fire Underwriters are in force there as they are on this side of the border.

The National Electrical Code makes no allowance for intermittent work so far as the size of the wires is concerned, but requires that the maximum current carried shall be less than the allowable amount for that size of wire. The current value may be calculated from the table under Rule Eight in that code. If Canadian installations must conform to another code, it should be consulted.

Westfield, N. J. G. H. MCKELWAY.

* * * *

Lining Up Sprockets for Chain Drives—Can some reader tell me the best and simplest method of lining up sprockets or shafts, for chain drives? We frequently change machines around and install new drives or replace old ones, and I should like to be sure that we are lining these up properly.
Decatur, Ill. J. L. B.

Referring to J. L. B.'s question in a recent issue of INDUSTRIAL ENGINEER it appears that he has reference to silent-tooth chains.

To obtain long life and quiet-running chain drives it is important to have the shafts of the sprockets parallel and the chain guiding medium in line. Aligning both sprockets with reference to their face or guide-link grooves is easily accomplished by use of a straight edge or a piece of string, similar to lining belt pulleys. Also, by observing the drive in action, final adjustments can be made laterally by moving either the driver or driven sprocket sidewise.

One method of checking to determine whether the sprockets are parallel is to take a piece of ¼-in. or ⅜-in. cold-rolled stock, about 1 in. shorter than the distance between the outside diameters of the sprocket teeth and fit a micrometer thimble to one end. This gaging rod is then placed between the two sprockets at one end of the sprocket teeth, a reading taken and checked against one taken at the other end. This gaging is done between the top of one tooth of the driver and the top of a corresponding tooth of the driven sprocket. The shafts are then adjusted until the reading at each end or side of the face of the sprockets corresponds to within 0.005 in.

As an alternative, if the elements for the gaging rod described above are not available, a stick of wood may be used. This is cut about 1 in. shorter than the approximate distance between sprocket diameters and a nail driven in each end. The heads of the nails are cut off and the ends slightly tapered and rounded. In this case the gage is used in the bottom of the tooth, measuring at the bottom of the corresponding tooth in the other sprocket. The nails can be driven in to suit the distance at one end or side of the sprockets, using a piece of tin as a feeler-gage under the nail point, and checking on the opposite side, making the necessary adjustments for paralleling. Greater care and patience are required for accurate alignment, as compared to the first-mentioned gage rod, but it can be done.

Also I would suggest studying the article on silent chain drives which appeared in the August, 1923, issue of INDUSTRIAL ENGINEER. E. H. LAABS.
Engineer, Printing Equipment Dept.,
The Cutler-Hammer Mfg. Co.,
Milwaukee, Wis.

Building Maintenance and Plant Safety

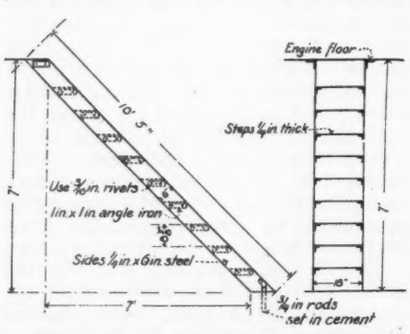
The object of this department is to give details of building maintenance procedure and best practice in safety work. Articles on ways of handling natural wear and tear or other depreciation, repair methods, rebuilding, extensions, cleaning and painting operations will always be welcome.

Strong and Simple Stairway for Use Around Machinery

WE HAD occasion some time ago to install two metal stairways, of the type shown in the illustration, in a power plant engine room, and they proved so satisfactory that a number of others of similar construction were built for other purposes.

When the engineer is called upon to make something of this kind, he has to do all the preliminary work for one job, unless he has such data indexed among the files of his trade papers or has happened to clip an article relating to that particular thing. As I had to do the necessary planning for this installation, the design used is presented here for reference. These stairways are easy to ascend, as the angle is 45 deg., which is unusually comfortable for an industrial installation, although this is a little steeper than architects in the building trades will specify.

Besides engine and boiler rooms, where metal runways, stairs and ramps are essential, there are any number of applications in the industrial field. In the manufacture of foodstuffs, cloth, floor coverings, artificial leather, and in many other lines automatic machinery of great length (and considerable height) is used for a number of continuous processes, and there is an upper deck that must be reached by ladders or stairways. The latter are far preferable and safer, and they are as low in cost.



Details of an inexpensive metal stairway for industrial plant use.

The design of stairway shown has ample safety for any load that can be put upon it by all the men who can possibly crowd on it at one time.

The side rails are made from ¼-in. by 6-in. steel. The ends are sheared at an angle of 45-deg. or they may be bent over to give additional support and for fastening. Pieces of angle iron are riveted to the insides and on top of these the step plates are laid and riveted. The step plates should preferably be of 8 in. width, although narrower plates can be used if there is any object in so doing.

Where it is possible to use it, corrugated plate is recommended for the step plates as giving surer footing for the workmen. A more elaborate design of step would include a riser at the back, set ½ in. above the step, to allow brushing out the dirt.

As shown, the upper ends are fastened to the engine floor, or deck. At the bottom, ¾-in. rods flattened out on top were riveted fast to the sides of the stairway and placed in holes drilled in the concrete floor; later the space around them was filled in with cement.

There are cases where such a stairway might develop an objectionable sway. Conditions of loading, vibration in machinery, or the use of thinner side rails might cause this. To combat anything of this kind, two diagonals on the back (under side) of the rails would stiffen the structure; or, riveting two or more of the step risers to vertically-placed pieces of 1-in. angle, would effectually steady the stairs.

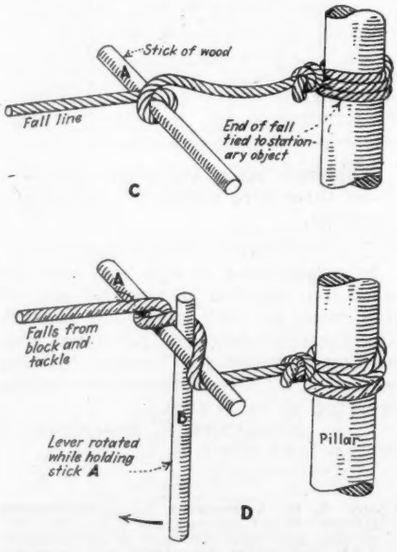
It would, of course, be advisable to erect a hand railing alongside this stairway so that a man could catch himself in case he should stumble or slip. In damp or oily places it is well to use a special safety tread. There are several makes of these available.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

Using the "Spanish Windlass" to Increase the Pull

THE Spanish windlass has been found to be a big help where a tremendous pull is to be exerted in shifting heavy machinery into place with a block and tackle, and where it is not possible to get enough more men on the fall line to handle the load. Although it may not be new to the sailor or experienced rigger, perhaps some of the readers of INDUSTRIAL ENGINEER may find it a big help at some time or other.

All that is required to make a Spanish windlass is two sticks, preferably hardwood, of convenient length. The ends of the fall are fastened around a stationary object or pillar with a little slack in the line. Referring to the illustration, stick (A) is given a twist into the line so as to form a round turn of rope (C) about it. Stick (B)



How a Spanish windlass may be applied to the end of a fall line from a block and tackle in case a load gets stuck and the men available cannot move it.

is then placed at right angles to (A). As will be seen, the rope comes across the back of (B) and on top of stick (A). Stick (B) is rotated as a lever in the direction of the arrow to wind up on the line. This operation is easily understood from the drawing.

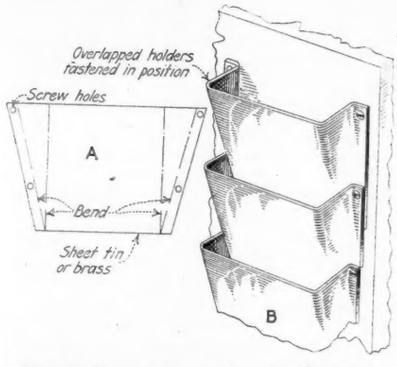
This arrangement is not intended to be used for making a long pull, but it is handy for giving the extra pull that is necessary when the weight is stuck and there is not enough "beef" available to make the grade.

Oakland, Calif. S. H. SAMUELS.

Simple and Easily Constructed Filing Rack

WHERE a vertical holder for cards or papers is needed, which will separate them in any desired order, the type of holder shown in the accompanying illustration can be made at practically no cost.

The individual pockets are made from a single piece of sheet tin or brass that is bent at the places shown at *A* to the shape shown at *B* in the accompanying illustration. The holders are held at



The holders are made of sheet tin or brass and bent to the shape shown. They are arranged in vertical columns to which parallel rows can be added.

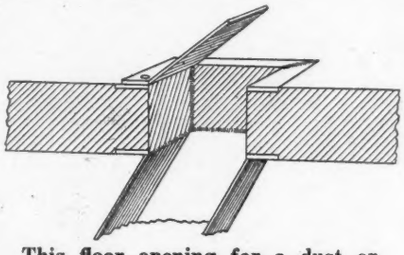
the edges with small screws or tacks. This form of holder permits of overlapping and can be arranged so as to form one continuous column as shown at *B*. If more pockets or holders are required, parallel rows can be added.

Washington, D. C. G. A. LUERS.

Trap for Floor Sweepings Which Aids in Factory Housekeeping

INDUSTRIAL housekeeping is ordinarily much more easily done if some provision is made in the plant for removing the sweepings and other debris. In woodworking plants, for example, it has been customary to have doors or slides opening into an exhaust pipe into which sweepings or shavings could be pushed so as to be automatically removed by the same suction which removes the shavings from the machine. Chutes could be used in many other industries for a similar purpose. In cases where the material is bulky, as in the woodworking industry, it would probably be necessary to put some suction on it, although for many lines of work a straight chute can be used with an open discharge at the end.

An ingenious floor trap for such dirt removal is shown in the accompanying sketch, through the courtesy of The Linde Air Products Co., New York City. This consists of a rectangular box of channels cast in the concrete floor, with flanges out and equal in depth to the



This floor opening for a dust or sweepings trap was built up by oxyacetylene welding and cast into the floor.

depth of the floor. These channels were oxyacetylene welded at the corners. An enclosed chute leading from this box to a waste material conveyor is welded to the bottom of this and the top is covered by a sheet steel door. When the floor is swept, it is merely necessary to open the door of this trap and push the sweepings into the chute. If it is to be used in connection with a suction line care must be exercised to see that it is a tight fit so as not to lose too much of the suction when not in use.

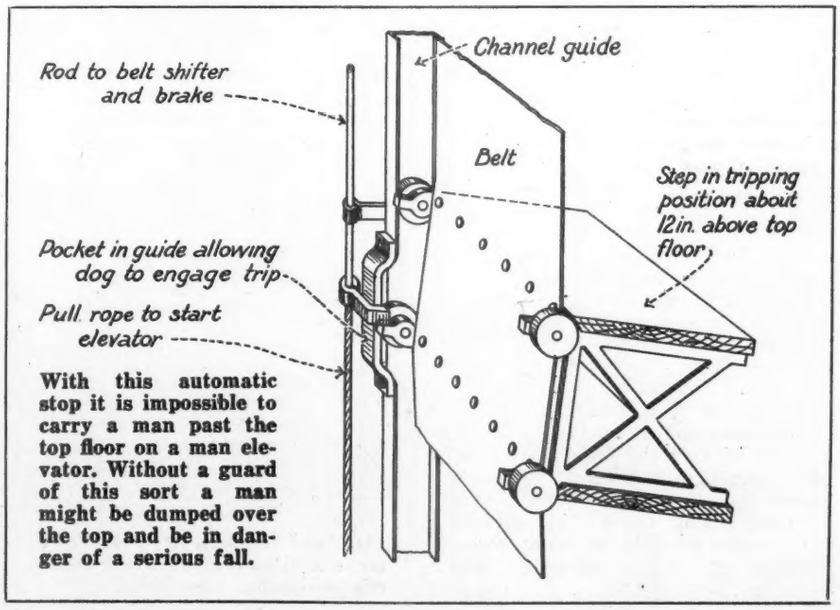
Stop Which Prevents Riding Man Elevators Past Top Floor

IN SOME food products and other similar plants, where the supervisory force and others connected with the industry must travel frequently from floor to floor, it is the practice to install what are known as man elevators. These consist of vertical belt conveyors with steps and hand holds. The belt is in continuous operation, so that a man may ride up on one side of the belt or down on the return side of the belt. For this equipment there are, in general, two styles of steps. One of these steps is so constructed that when it reaches the top of the flight it tips over so that it is in the proper position for the man to ride down on it. Sometimes however, these do not tip and when the man steps on it, may in some cases cause an accident. The other is a double type of step as is shown in the accompanying illustration. The hand holds are riveted to the belt at the proper distance on each side of the step.

These man elevators are safe and a big convenience in carrying a few men between floors. Otherwise, if a man had to wait for an elevator or had to walk the three to five floors between operations, supervising would be an exhausting job. Practically the only danger involved is through trying to carry tools or other objects up or down on the man elevators, or in neglecting to step off at the top floor. Supervision and discipline are perhaps the only methods of preventing individuals from carrying objects while riding.

At the Battle Creek, Mich., plant of the Postum Cereal Company an elevator of this type is installed in the five-story Post Toastie building. Here the special device shown in the accompanying illustration automatically shuts off the man elevator in case the person riding on it should neglect to step off before he has passed a foot above the top floor. It will be noticed from the accompanying sketch, that rollers supporting the step ride in a channel guide. A short piece of the metal is cut out of the side of one of the channels and a strap or pocket is fastened on, as may be seen.

When a man is riding on the elevator his weight forces the lower roller guide up against the side of the channel and when it comes to this pocket, throws out far enough to catch into a dog which trips the starting rope of the elevator. When the step is not loaded the roller goes straight past the pocket in the guide and does not trip.

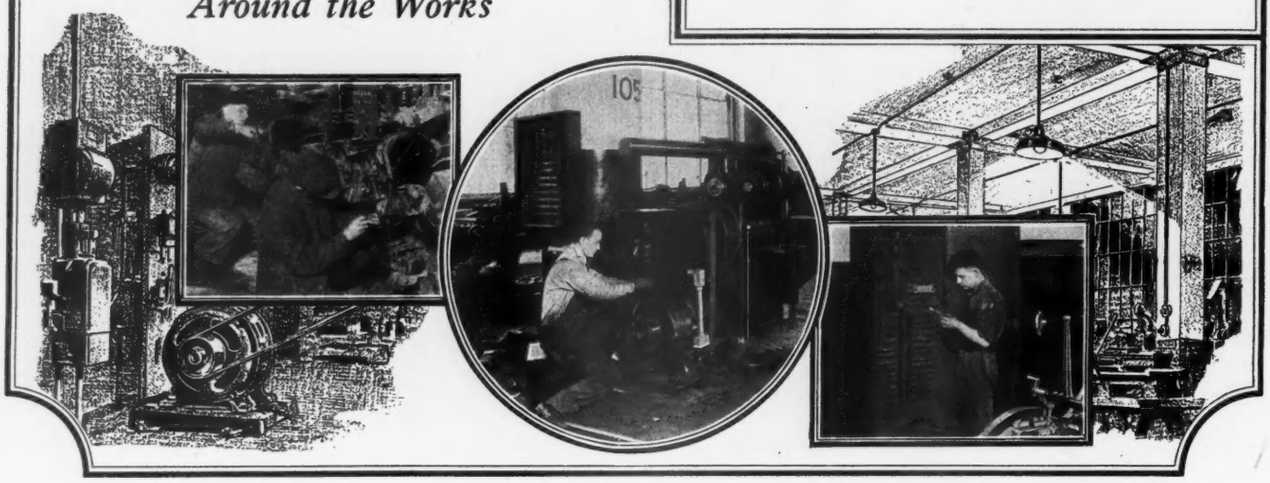

Channel guide
Rod to belt shifter and brake
Belt
Step in tripping position about 12 in. above top floor
Pocket in guide allowing dog to engage trip
Pull rope to start elevator

With this automatic stop it is impossible to carry a man past the top floor on a man elevator. Without a guard of this sort a man might be dumped over the top and be in danger of a serious fall.

Electrical Service

Around the Works

For this section ideas and practical methods devised to meet particular operating conditions are invited from readers. The items may refer to inspection, overhauling, testing or special installations.



Easy Method of Attaching Conduit, Cleats, or Bolts to Concrete

WHILE fastening conduits, knobs, cleats or bolts to concrete walls or ceilings may be done in various ways, it is often difficult to make a rugged and substantial job. We have lately been using a method that has proven itself a time and money saver and is hereby passed along.

In most industrial plants, compressed air is available and it is only a matter of a length or two of air hose to get it to the place where it is necessary to mount the material on the concrete surface. We buy star drills in quantities and machine the shanks to fit the sleeves of the air hammers. These, together with the air hammers, enable us to drill holes in concrete quickly at a very low cost. Wherever we think that we need to anchor a conduit, knob, cleat or other piece of equipment to the concrete, we drill a hole in it, and tamp the hole full of Smooth-On No. 1 (made by the Smooth-On Mfg. Co., Jersey City, N. J.) which is mixed with water until it has the consistency of soft putty. The knob, cleat, block or other device that is to be fastened to the concrete is then placed over the hole and a wood screw driven home into the soft Smooth-On. It is supported by a brace in this position for an hour or so and as soon as the Smooth-On has hardened it will be found impossible to pull screw, fitting or block loose.

For conduit work we prefer mounting wood blocks on the concrete and fastening the conduit to the blocks, thereby giving clearance for turning the conduit fitting.

We prefer the Smooth-On to lead anchors or expansion bolts for the reason that the size of the drilled hole in the concrete is important when using expansion bolts or lead sleeves, whereas with the Smooth-On it is immaterial.

It is also possible to mount bolts in concrete by drilling somewhat larger holes and setting the head of the bolt in the hole and tamping it full of Smooth-On, leaving enough of the bolt extending beyond the face of the concrete to allow for attaching anything that is required.

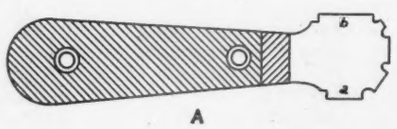
We are convinced that this method makes as strong a support in concrete as is secured by anchor bolts and sleeves and surely it is much cheaper and faster. Holes that are a little out of line can be used by enlarging them until they are in line and then filling both the hole and the mistake with the Smooth-On.

Plant Engineer, S. W. STEARNS.
Gardner Machine Co.,
Beloit, Wis.

Handy Tool for Inserting a Renewable Fuse Link

THE accompanying sketch shows a handy tool for inserting renewable links in Economy renewable fuses. It has been found in practice that some tools commonly used do not press the end of the links tightly enough into the containers. When a screw driver is used the slotted plugs are badly mutilated.

The sketch is self-explanatory. The bit, which runs through the riveted handle, is made of finely tempered steel. Instead of the edges being tapered, they should be ground as shown in (B), which lessens the tendency for the bit to slip out of the slot.



A

B

This tool renders it possible to make a firm contact when inserting renewable fuse links.

Portions (a) and (b) of sketch (A) are used for 30-amp. and 60-amp. sizes, respectively, as these sizes require a greater leverage to make a firm contact.

W. L. STEVENS.
Construction Engineer,
Smith Robinson Co.,
Vancouver, B. C.

Break in Power Line Cause of Obscure Trouble

A VERY puzzling incident came to my attention a short time ago, which I think may be of interest to readers of INDUSTRIAL ENGINEER. A 10-hp. d. c. motor operated on 500 volts had been sent to the shop to have the armature rewound. It was the only motor the owner had operating at this voltage. After the repairs were made, it was tested at the shop, proved to be in first-class condition, and was finally set up on the job. When the current was switched on, the armature refused to turn. The belt was removed, the bearings tried, fuses tested and connections checked, but without any results. A man from the Public Service Company was called in twice and claimed everything was all right up to the service switch.

We had spent about a day on it so far and felt stuck, good and plenty, but there was still one thing left for us to try and that was to measure the current to see if we were really getting enough power to run the motor. A meter was not available; so we fused across the main switch with 10-amp. fuse wire, threw in the switch, and the fuse wire held. Of course that told us our trouble. The Public Service Company was again called and their man tested the line with lights the same as we did and told us the line was O. K. so we had to convince him that it was not. This time we shorted the main switch with a screw driver and when nothing happened he called their repair truck. After tracing the line back, they discovered a broken wire lying in water in a manhole. That showed us why we had lights, but no power. After

repairing this break everything turned out satisfactorily.

This puzzling trouble can be told quickly, but it took us about a day and a half to get this motor running.

WALTER C. BISCHOFF.
Nesbit Electric Co.
Newark, N. J.

How Electric Heat Supplanted Steam for Preheating Wood Before Gluing

IN MANY high-grade woodworking plants it is the practice to preheat the wood before gluing to secure a tight bond. It is thought that preheating opens the pores in the wood so that the glue when applied penetrates the wood and makes a better joint. This is the practice at the Boston, Mass., plant of Horn Brothers who manufacture cabinets and interior finish.

For a number of years a steam-heated box had been used for this operation. It was necessary to operate a small steam boiler during the summer months for the heating of only this box and the glue pots. About a year ago, it was suggested that a saving could be made by heating this box electrically instead of by steam. The top of this box, which is 12 ft., 6 in. long by 2 ft., 6 in wide by 2 ft., 6 in. deep, is divided into two sections so arranged that either can be opened as desired as shown in the accompanying illustration. The interior of the box is lined with asbestos which is protected by sheet metal. The steam coil is in the bottom, as is also shown.

As it was the original intention to heat the box in summer by electricity and by steam in the winter, the steam coil was left intact and the electric heating elements placed at right angles underneath. As there are about 34 sq. ft. of steam pipe radiating surface in the coil, it was estimated that about 2½ kw. of electrical capacity would be sufficient to maintain the desired temperature. In order, however, to reduce the time of heating up in the morning, 4 kw. were installed in eight units of 500-watt, 230 volt, Westinghouse space heaters. These were so arranged on a double-throw switch that either full or half-heat could be secured. After the equipment was in operation it was found that it was necessary to leave the high heat on for only a short time in the morning. The switch could then be thrown to the half-heat position.

This view of the interior of the box shows how the space heaters were placed.

At the time the wood box was arranged for electric heating it was also decided to do away with the steam-heated glue pots. A circuit was run along underneath the work benches with outlets arranged at convenient points. Two 1-qt. and one 2-qt. Westinghouse electric glue pots were then installed. This arrangement proved much handier for the workman, for he had the glue at his bench. It was not necessary for him to walk across the room as he did when the steam-heated pots were used.

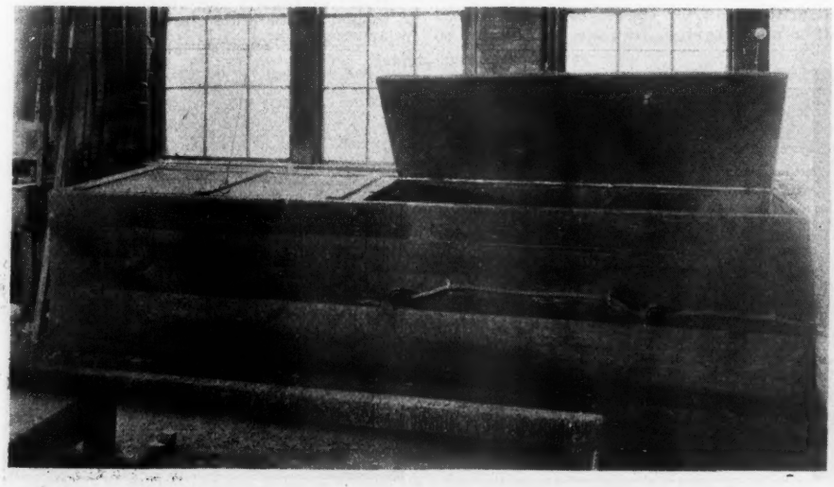
Although it was the original intention to use the electrical equipment only during the summer, experience showed that the operation was so economical and convenient, that the owner is now considering using the electrified equipment the year round.

The cost of this installation amounted to about $225 including three glue pots, 8,500-watt space heaters, and all necessary wiring including a run of about 50 ft. of wire from the service entrance. The average monthly energy consumption of this equipment is 370 kw.-hr. which at 3 cents per kw.-hr. amounts to about $11. J. L. FADEN.

The Edison Electric Illuminating Co.,
Boston, Mass.

Formerly steam was used in this box to preheat wood for gluing.

This required that a steam boiler be operated during the summer. Now, eight 500-watt space heaters with a double-throw switch so that half of them can be turned off after the box is heated up, were installed beneath the steam coil. It now costs about $11 monthly to heat this box and three glue pots with electricity, which is much less expensive and laborious than keeping up steam in the boiler.



Importance of Proper Design in Illumination of Factories

UNTIL the past few years man has, when using artificial illumination, been accustomed to local lighting from small and few (usually one) light sources. He has therefore, with good reason formed the mental habit of believing that the nearer his eye and his work are to the source of light, the better will he be enabled to see. However, the very conditions which formerly enabled him to get the best results from his lamp may now constitute the least efficient arrangement.

Lamps are now so large that they need not be so near the object lighted in order to give good illumination. They cost so little that a number may be used with a more than proportional increase in results. Also, they are now so bright that they should no longer come within the range of vision, or discomfort and injury to the eye will result. Therefore, the lighting habits of generations must be broken if we are going to make the best use of our eyes.

Before we started using artificial light we had the general illumination of the sun; to this light we were physically very well adapted. Our eyes are shaded by our brows from the glare overhead, and are able to adjust themselves to the slowly changing intensity through the day.

Our artificial lighting habits were against the laws of nature, but as we did not know how to make very good lamps, it did not matter much. But now that our present lamps produce light of an intensity more comparable to sunlight, we are being forced to change some of our habits.

Properly designed lighting systems are now as good as sunlight, and sometimes better. These are systems of general illumination using a number of large-sized luminaires mounted relatively high and so spaced as to give a uniform lighting of the working plane. No other system can be better for any useful application. A good general illumination produces the effect of working out-of-doors, with the sunlight not too bright. When the work to be done is of such a nature that the illumination from the sun would not do, local lighting must also be used. If light must be projected into cavities or under objects, portable or adjustable brackets are required. The light must be well shaded from the eye, or the undesirable effect of the glare will more than counterbalance the value of the additional illumination obtained.

Glare in the eyes in time injures them or at least affects the vision. Injury also may be caused by too intense light entering the eye or by the alternate reception of light of moderate and low intensity. Glare effects may be produced by direct or reflected rays, when the lamp filament or its reflection comes in the line of sight. They may also be

produced by a flicker of the light or by the cone of vision covering alternately fields of higher and lower illumination.

For the above reasons, lamps should be hung above the range of vision or else shaded or screened; glass should not be used on desk tops; 25 cycle or fluctuating voltage should not be used for office lighting; belts, spokes of wheels, or other parts of moving machinery should not be permitted to produce flickering where any fine work is to be done; and local lights should not be used on desks or drafting boards. When local lights are used they should not produce a greater illumination than that received from the main lights which they supplement. In industry local lamps should be employed only to obtain light rays at an angle to those giving the general illumination.

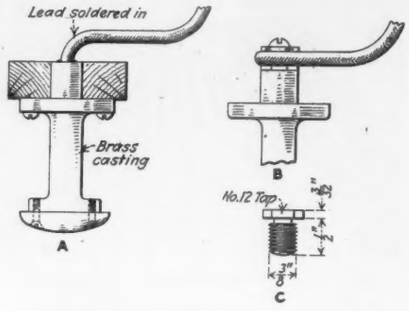
Electrical Engineer, D. W. BLAKESLEE.
Jones & Laughlin Steel Corporation,
Pittsburgh, Pa.

How Starter Trouble Was Cured by Applying a Little Common Sense

AT ONE time we had a 10-hp. induction motor with a General Electric Type CR, starting compensator which will be recognized as quite an old timer. This compensator had always given trouble through breaking of the leads to the cylinder. About once a year we would have to shut down the woodworking room served by this motor while the starter was being fixed up. The shutdown meant, in addition to the half-day's work of making repairs, a wait of one to four days to get an electrician, as we then depended on outside help for work of that kind.

On one occasion this starter went bad again at a time when we couldn't get anyone to fix it right away and we just could not wait. We decided to tackle the job ourselves; so we took the whole thing apart, carefully marking each wire as we went along. Sure enough, two leads were broken off where they entered the shoe sockets.

The leads were soldered in a hole in the brass casting as shown in the diagram *A*. Two disadvantages appeared to us in this construction. The wire had to be bent sharply in order to enter the socket, and with the soldered fastening there was no chance to make repairs except by dropping the cylinder out of the case and pulling the leads along with it. If the bend were avoided there would be no initial stress on the wires to start a break and if a screw fastening were adopted, repairs could be made by merely taking off the front cover of the compensator, with no wires to thread in and out and no oil pan to handle.



Originally the leads to the cylinder of starting compensator were sweated in as in A. The change in B, using a screw connection, eliminated lead breakage and made quick repairs possible.

We altered the fastenings of all the nine shoes as shown at *B*. It took a little time in the machine shop to make the necessary parts but it was a good job when completed and we saved something by not having to sweat in all the wires. The holes for the reception of the leads and solder, were tapped out and into these we screwed brass bushings that had hex. heads of ample diameter. On top of these, the leads were to be secured by a conventional brass screw and washer. These screws headed upwards and when the compensator was re-assembled, they could still be worked at by using a long screwdriver. As noted in the drawing, the changed construction allowed the leads to enter and be fastened at an easier angle than before, while the sharp bend where they had broken so often was avoided altogether.

Long usage since then has shown that the change was a good one, for no more leads have broken. The men in the shop have remarked that they wish a wire would break just to give us a chance to demonstrate how easy it would be to make repairs, in contrast to the old, familiar delays. This alteration saved the company the cost of a new starter, for one was about to be purchased because of the high upkeep of the old one, but now the starter is apparently good for our lifetime.

This same trouble of wires breaking is very annoying in a busy department (and who ever knew of any breakdown to occur where the department wasn't busy?). Long experience has shown one way to avoid these continued breaks. It is customary to cut back the insulation and stick the wire on again. Then the first thing you know, the wire is a bit short, and the constant bending back and forth that a cylinder wire gets can be made serious in no quicker way than by having it occur on a taut wire. The remedy is to splice the wire or put in a long lead, so that there is plenty of slack; the wire will then stand twice the amount of flexing before it finally breaks.

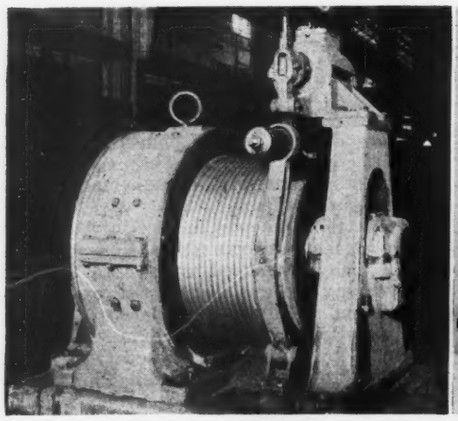
DONALD A. HAMPSON.
Plant Superintendent,
Morgans and Wilcox Mfg. Co.,
Middletown, N. Y.

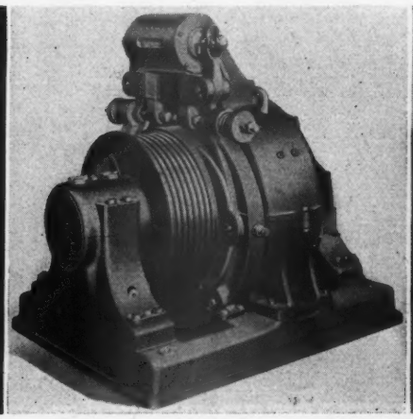
Correction in Article "Electrical Devices in the Path of Power Service"

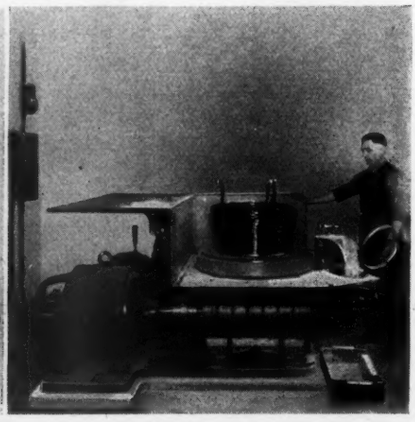
AN ERROR was made in the caption to the illustration on page 75 of the February issue of INDUSTRIAL ENGINEER. In this caption the words "left," "middle," and "right," were inadvertently interchanged, thus incorrectly crediting the three manufacturers with the equipment illustrated. The corrected caption and the illustrations are shown below.

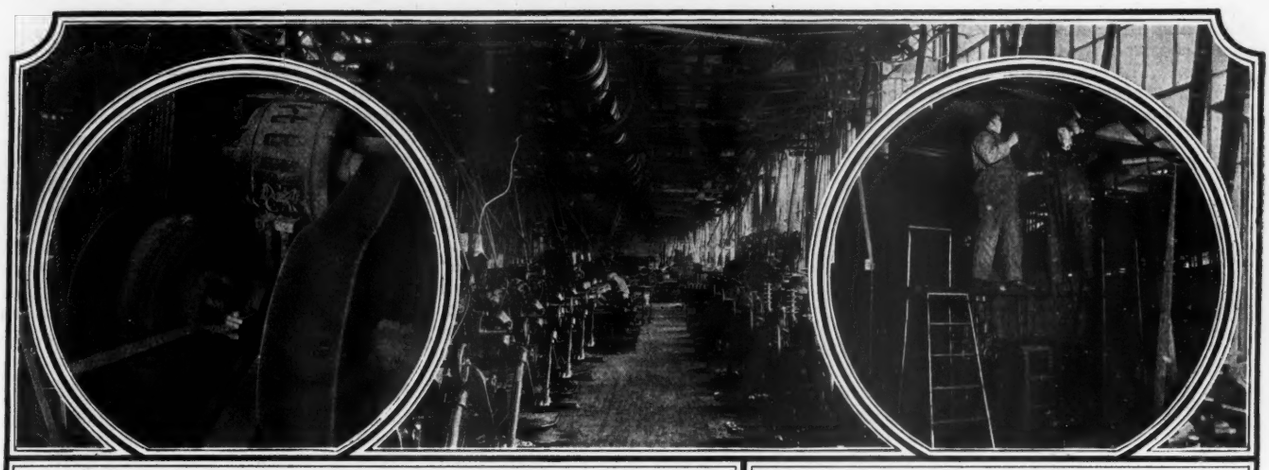
Three motor drives that were designed to fit the user's special requirements.

At the left is shown a log carriage drive developed by the Westinghouse Electric & Manufacturing Company. The motor shown is rated at 35 hp. with a speed range of 10 to 80 r.p.m and is supplied with variable-voltage, direct-current power from a 30-hp., motor-generator set. In the center illustration is shown a new gearless, traction elevator motor built by the Allis-Chalmers Manufacturing Company of Milwaukee, Wis. This is a slow-speed, shunt-wound motor, the armature shaft of which is coupled directly to the hoisting drum. At the right is shown a special variable-speed, motor application made by the Reliance Electric & Engineering Company of Cleveland, Ohio, to a wire drawing machine. It is said that increased production is obtained with this individual drive arrangement.









Mechanical Maintenance of

Power Drives

This department will furnish mechanical details of installation, operation and maintenance of equipment in the path of power service from the first mechanical driving element through transmitting equipment to all driven machines.

Record System For Spare Pulleys and Other Transmission Equipment

FOR a number of years I have used the following system for keeping a record of spare pulleys and other transmission equipment and have found that it enables me to locate all such equipment quickly.

Every pulley, gear, coupling, or other piece of transmission equipment is given a number upon being placed in storage. This number is painted with white paint on the face, arms, hub or side in sizable figures. Upon a cloth tag fitted with a tie wire instead of a piece of string, is entered all of the data regarding the piece of apparatus that is being numbered. This tag is shown at the left in the accompanying illustration. It will be noticed that this tag has a perforated line across the upper third. After the tag is filled out, the two parts are separated at the perforation, the upper part with the wire is attached to the pulley or other piece of apparatus being recorded, while the lower and larger part is placed in a file in the office of the foreman of the machine shop. In this file the tags are grouped according to pulley diameters or some other distinguishing size.

The same data that was entered on the tag is entered on a 3-in. by 5-in. card as shown at the right in the illustration. This card is kept in a file in the office of the superintendent of the *Mechanical Department*, the office in which all the engineering work is planned and laid out.

Whenever a pulley or other piece of transmission equipment is taken from storage and put in use, that part of the tag that was attached to the pulley is removed and taken to the office of the machine shop foreman. Here the corresponding part of the tag is taken from the office files and the two parts are taken to the mechanical superintendent's office. The proper 3-in. by 5-in. card is then taken from the file in the mechanical superintendent's office and this card with the two portions of the tag are destroyed. In this manner both the machine shop's and the mechanical superintendent's files show only those pulleys or other apparatus that is in storage.

The same system can be used for hangers, couplings, gears, motors, pinions, in fact, for any class of spare material held in storage, the only change necessary being in the data entered on the tags and cards. One important point to be noticed is that in storing the spare equipment it should be so placed that the numbers which are painted on it are plainly visible. If possible, it is well to group the apparatus according to types or size of apparatus.

Lawrence, Mass. A. J. CALHOUN.

F710-2M-12-15-19

Date JAN. 31/22 No. 6599
Diam. 24"
Face 4" CR.
Bore 1-15/16"
RETURN THIS TAG TO THE MASTER MECHANIC'S OFFICE

Date JAN. 31/22 No. 6599
Diam. 24"
Face 4"
Bore 1-15/16"
Lgth. Hub 4½" Diam. 3"
Wood Rim / Cast Iron ✓ / Steel — Split / Whole ✓ — Crown ✓ / Flat
Condition GOOD
Set Screws 2
Keyway
Remarks 6 PULLEYS LIKE THIS
Where Stored #14 MILL
Reported by A.B.

All data regarding the pulley is placed upon the tag shown at the left.

The upper third of the tag is tied to the pulley and the lower part is placed in a file in the machine shop foreman's office. The data on the tag is also entered upon the card shown at the right. This card is filed in the mechanical superintendent's office where all of the engineering work is planned and laid out. In this manner both the engineering department and maintenance department have a record of all pulleys that are in storage.

F 687 2000 1 1930 J 709

Number 6334 Date JAN. 31, 1922
Diameter 24" Face 4" Bore 1-15/16"
Wood Rim / Cast Iron ✓ / Steel — Split / Whole ✓ — Crowned ✓ / Flat
Set Screws 2 Length of Hub 4½"
Keyway Diameter of Hub 3"
CONDITION GOOD
REMARKS 6 PULLEYS LIKE THIS
STORED IN #14 MILL REPORTED BY A.B.

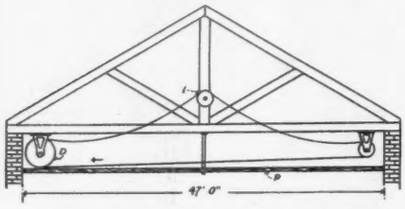
Easily Installed and Simple Method of Handling Long Belt Drive

IN a certain printing plant a battery of cylinder presses is installed along one side of the room. These presses are driven from a line of shafting hung from the bottom chord of the roof trusses and placed close to one wall. The center of the room is used for storage of paper and printed matter.

The growth of the business necessitated the installation of some small auxiliary machinery, such as stitchers and stapling machines. These are light power machines that are usually placed flush with the front edge of a bench, so that work can be handled from one side to the machine and then passed out of it and on the other side of the bench without any lifting or unnecessary piling.

These light machines were installed in two sets near opposite ends of the

room and in connection with benches along the wall away from the cylinder presses. The arrangement was ideal from a material-handling standpoint. Power was to be supplied to the two



The slack side of the belt was supported on an idler pulley, to keep it from dragging on the running side.

sets of machines by belts from the line-shaft, a short overhead shaft having been installed to serve each group.

The illustration shows the belt drive which was eventually adopted. It was worked out by the master mechanic after the direct drive which had been originally planned had failed from dragging of the belts. The room is nearly 50 ft. across and, as every engineer knows, the sag in a belt between such centers is considerable, even though it be stretched too tight for proper free running.

The pulley (D) is the driving pulley; it was made as large as possible. The driven pulley is much smaller. A stout plank, (P), runs underneath for safety and takes care of any undue sag in the driving side which is, fortunately, on the bottom. An idler, (I), raises the upper or slack side of the belt free and clear.

This belt drive is free-running and neat; it requires no attention and overcomes in an ingenious way the risk of tangling that is always present when two long belts touch, or the slack side touches the running side of the same belt. The arc of belt contact that is obtained on both the driving and driven pulleys is all that could be wished.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans and Wilcox Mfg. Co.
Middletown, N. Y.

Savings Made with Variable-Speed Transmissions on an Assembly Conveyor

VARIABLE-SPEED transmissions enabled a Detroit automobile body manufacturer to reduce motor sizes 33⅓ per cent and effected a power saving of nearly 1 hp. on every conveyor. The savings from these sources totaled $864.54 a year, which was a 41 per cent return on the investment, also with these transmissions, production can be scheduled more closely. Under the former method of production, bodies went through the shops on trucks, but the installation of a few conveyors quickly proved the economies which could be effected, and as a result 12,000 ft. of conveyors were installed.

These conveyors handle the bodies during paneling, painting and trimming operations. Their use effected a 10 per cent saving in labor, which meant 500 men, whose annual wages would be $975,000. Also, production was doubled with practically the same floor space. This saving was 250,000 sq. ft., worth $250,000 a year, which brought the total saving to $1,225,000 a year, not including interest on reduced inventory.

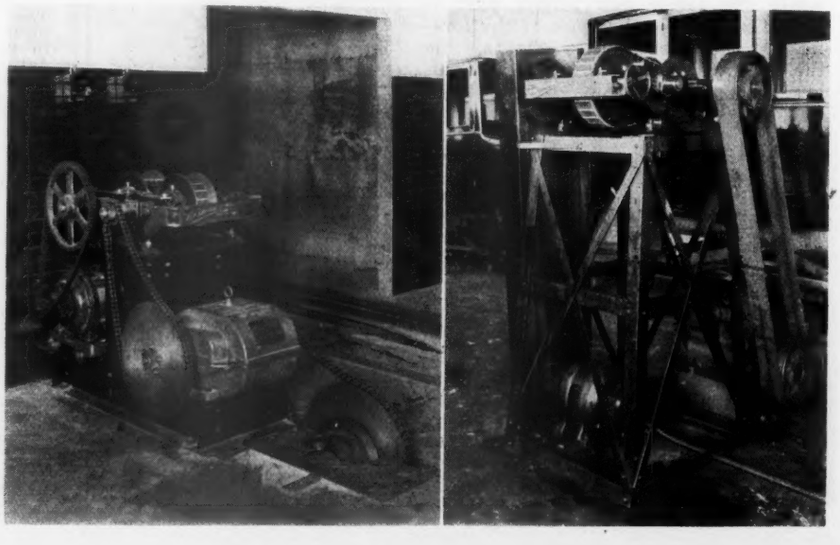
One of the most important factors in the success of a conveyor is the ability to control its speed accurately, for the speed determines the rate of production. For this work Reeves variable-speed transmissions (Reeves Pulley Company, Columbus, Ind.) were used, of a size capable of transmitting 6½ hp., at minimum and 10½ hp. at maximum speed. The maximum speed variation is 3 to 1. Conveyor speeds range from 13 in. to 40 in. per min.

Turning a handwheel on a transmission unit varies the conveyor speed over the entire range, in steps of less than 1 r.p.m. The exact speed desired can always be obtained almost instantly. This is quite a contrast to the former method of driving with variable-speed, alternating-current motors, most of which were equipped with common rheostats giving only eight or ten speeds. With this system the desired speed was not always obtainable, and even when it was secured it was subject to considerable variation as the conveyor load changed. Securing the desired motor speed was rendered difficult by the fact that each step on the rheostat produced a different increment of speed. Another disadvantage of this method lay in the fact that the motors required considerable excess capacity at rated speed in order to carry the load at low speeds.

By using these transmissions, these large, expensive, variable-speed motors and their rheostats were replaced with smaller, constant-speed motors. The average conveyor now uses a 2-hp. motor in place of the former 3-hp. motor. This saves about $60 on each motor, or $1,080 on the 18 motors installed. The savings in depreciation, interest, and repairs, due to this smaller investment total $197.64 a year.

There is also a saving in power, because the variable-speed motors are inefficient at low speeds; the loss in power is estimated at 0.75 kw. per motor, or nearly 1 hp. This means a saving of $666.90 a year in power, which brings the total saving to $864.54 a year. These savings will repay the entire original cost of the variable-speed installations in less than 2½-yr. The operating cost of the 18 transmissions is only $1.22 per day, a trifling amount to insure maximum results from a conveying system which saves more than a million dollars a year.

One of the greatest advantages of this transmission installation is that it enables production to be scheduled more closely. The schedule varies between wide limits; on some days production is three times as much as it is on other days. The transmission is set to give exactly the desired speed, and it will remain at that point. With the alternating-current motors this was impossible. Some plants vary the conveyor speed by changing pulleys. Obviously this method involves an expensive delay. It is suitable only where there is but one product and a constant production rate.



Two variable-speed power transmission units used on a body conveyor.

These are two of 18 similar installations in the plant of a Detroit automobile body manufacturer. The saving over the use of variable-speed motors on the 18 installations is $864.54 a year as explained, with other advantages, in the accompanying item. In the installation at the left the motor is connected to the Reeves variable-speed drive, shown at the top of the framework, through a silent-chain drive. The variation in speed is obtained by a V-belt on two sets of cones. As the cones are forced farther apart or closer together the belt rides lower or higher on the cones and so decreases or increases the diameter of the pulleys, which varies the speed ratio between them. To obtain the slow conveyor speed a further reduction, in a fixed ratio, however, is obtained through the roller-chain drive to the Palmer-Bee (Detroit, Mich.) mill-type speed reducer and the roller chain from it to the large gear in the floor which drives the conveyor. The installation pictured on the right is similar except that it has belt instead of chain drives and uses a Palmer-Bee worm speed reducer. Most of the conveyors in this plant are operated at a speed varying from 13 in. to 40 in. per min. even though driven by a constant-speed induction motor.

Some Reminiscences on Mechanical Repairs That Show the Value of Experience

HOW we used a piece of sewer pipe for a pattern, in place of making a wooden one, is a "kink" that saved us quite a little money on the first job and more on later ones. To lead up to this, however, it might be explained that the Jones Shirt Company asked us to make a set of new piston rings for their engine. The piston was out and we were told that we could come and measure it up at any time. We were under the impression that they had been running by steam all the time and so we hurried up there to get the work under way without delay. Upon arriving, it was disclosed that the plant had been operating for some time with electric power. A former management had hooked a 50-hp. motor to the lineshaft which supplied power to sewing machines and other equipment on the two floors. It seemed that the motor had been installed when it was found that the steam engine was taxing the capacity of the boiler.

This had been done in the Spring, when the days were long, and considerable economy had been effected. Then, in the Fall, they had hooked up to the public service for lights and had never again checked up on their total expenditures for power, heat, and light. The steam engine, in the past, had furnished power to the shafting and had driven a lighting generator from one of the flywheels. Steam could not be dispensed with as it was needed for pressing, steaming, and some other work, one battery of machines requiring steam at 90-lb. pressure. In view of this latter fact, the use of some motive power other than an engine should not have been undertaken without exhaustive proof of the need.

A new manager had investigated and found that his public service bills for light and power were relatively high. He found also that the boiler had a surplus capacity 'way beyond what was needed for heating purposes upstairs, and he was keeping a skilled man merely to attend the boiler. So, after quizzing some of the men who had known of former conditions in a general way, he had the piston removed for investigation and found what he had suspected: namely, that the amount of steam required for the engine had been due to leakage past the piston rings.

The engine cylinder was 9 in. by 12 in. There were two steam rings with the usual flat-lap rings of ½-in. square cross section. In their natural position, outside of the cylinder, the rings calipered hardly 9$\frac{1}{16}$ in. and there was a ¾-in. notch at the lap, poorly fitting. It was little wonder that the steam had blown by. Rings for a 9-in. cylinder should measure 9$\frac{3}{16}$ in. before compressing, in order to have the necessary spring to keep them steam tight.

A 9-in. cylinder was something that we had never fitted before and we had no pattern for the rings; nor could we find anyone else who had; nor could anything we had around be doctored up for this purpose. The management wanted two extra rings made at the same time. That meant a pattern about 5-in. long. The cost of making such a pattern was out of proportion to the rest of the job and some other way was sought. It ended in using a piece of sewer pipe.

We found that 8-in. sewer pipe measures just 8 in. inside and that the outside diameter is 9$\frac{9}{16}$ in., both by shrink rule. This was exactly what we would have made our wood pattern, had we been forced to it. We bought a length of this tile pipe for 28 cents (a length that had a broken bell end) and cut off a section about 9 in. long, using a chisel for nicking all around, breaking off our piece, and then grinding the ends fairly smooth.

This was our pattern. We had purposely cut a piece longer than was absolutely necessary in order to give the molder something to handle in lifting, and to avoid the almost certain breakage had we attempted to cut off a ring only about half as long.

The only fault with the ring as cut off was its roughness. This roughness is found on all clay products of this sort, but in somewhat exaggerated form on tile pipe. These pimples all over the surface could not be filed off—glass hard from the kiln—and we had no good way of grinding them and actually bettering the surface. The piece was given to our machine painter with instructions to "apply three thick coats of machine filler today and sandpaper inside and outside smooth tomorrow morning." He did—and we had the nicest kind of a pattern. And not long after we had a call for the same size ring from some one else.

As there are many engines of the 9-in. bore in use, this kink will be of value to others who are faced with the problem of a cheap pattern that must be charged against the one job. The total amount of labor on this pattern was one hour, exclusive of the trip to the tile yard. The fact that the tile pipe is measured on the inside, and runs close to the nominal size, makes other sizes available for piston ring patterns. Note that the machined sizes required in the above case were 9$\frac{3}{16}$ in. and 8$\frac{3}{16}$ in. and that the tile diameters leave just a nice amount of metal to cut off. The inside diameter of the blank comes a little smaller from the jarring a molder gives the pattern to loosen it from the sand.

This is an illustration of one of those cases which are in the minority—where steam is cheaper than electricity. If the engine and generator had not been on hand, the case might have been different, but both had been put in years before and were still in splendid condition—a N. Y. Safety Steam Power engine and a Triumph (Chicago) lighting generator. There are many industries that require steam for processes but not many that have to use high-pressure steam; when they do, and when there is sufficient boiler capacity, the matter of steam power should be thoroughly considered before changing.

This is also an illustration of the high cost of taking some one's word without investigating. Some ex-engineer had reported that the engine used so much steam or that it cost more for steam than it would for electricity, all without knowing why so much steam was used. The manager, it must be said in his defense, had taken the man's word for it, thinking he was competent and not having the time or the knowledge to prove things for himself. More than that, he was used to electric power and knew its low cost and freedom from attendance charges; hence he bought a motor for the plant. Not until the new manager came along, with either more time or more determination to dig into the facts, did the real state of affairs come to light.

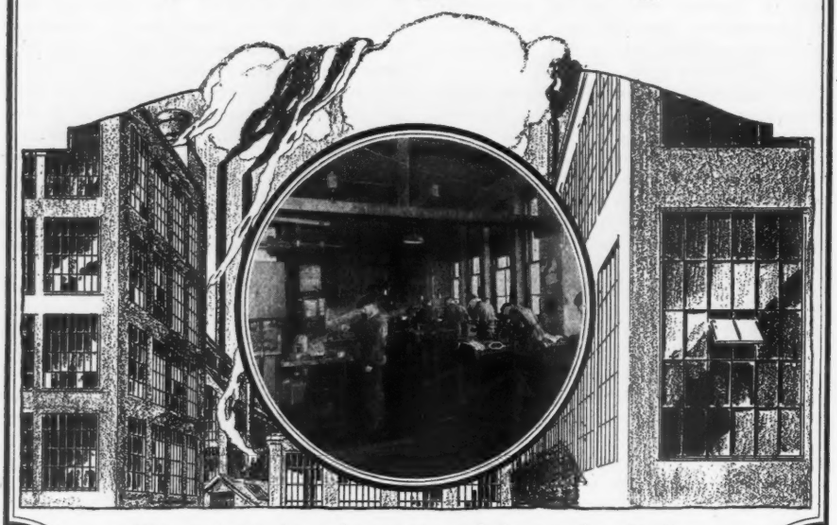
The writer ran across a parallel case some time back when measuring for piston rings in a piano factory. The steam engine ran lineshafts on the lower floors and drove a generator supplying power to motors on the three floors above. What was his surprise, on taking the piston out of the engine, to find that there were no rings in it at all. When the superintendent was called in, he explained that six years before they had paid (and paid well) to have the engine overhauled and new rings had been one of the stipulated jobs. Both this man and the proprietor doubted the writer's word that rings were supposed to be in the slots. They thought that the bull ring was the necessary part.

However, there had been a great deal of steam used and permission was forthcoming to make up the split rings. In due time they were installed, the work being done at night. Early the next morning, there was a phone call from the proprietor to say that everything was fine and the thing which had worried him most was entirely remedied, this being the great amount of steam that had gone out of the exhaust.

In these electrical days we are so used to snapping a switch or pressing a button that we are stuck when something puts electricity out of our reach. There was a plant not far from us that was located along a good stream. They had their own hydro-electric system furnishing power to machines located on different floors. They also had a pair of boilers for steam purposes and there was a steam engine standby that could be belted to the generator if necessary. It hadn't been necessary for several years, but at last a drought of several months' duration made the engine necessary. The handy man around the plant had been instructed to get things ready and he had oiled up, put a wrench on all the bolt heads one way or the other (including the eccentric and the valve stem) and was ready to start. His way of starting, and of getting the right direction of rotation, was to have some one turn the engine over while he gave her steam—then, "whichever way she was started she would go." Well, she went the wrong way for the generator and two men on the flywheel couldn't make it go the other way. That's how we came to get a hurry call to come and adjust the engine.

DONALD A. HAMPSON.
Plant Superintendent,
Morgans & Wilcox Mfg. Co.
Middletown, N. Y.

In the Repair Shop



This section is devoted to repair work, large and small. Special attention is given to shop or bench tools and short cuts or improved methods. Contributions are always welcome.

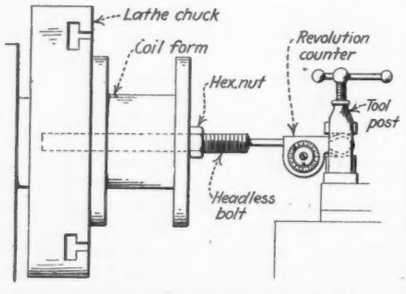
Novel Use of Revolution Counter in Winding Coils

RECENTLY the writer had occasion to call into use a unique arrangement which may prove interesting to some of the other readers of INDUSTRIAL ENGINEER.

A certain job called for the rewinding of a circular field coil of quite large dimensions. It was necessary to have exactly 1,035 turns of wire on the coil. Anyone who has had experience in winding circular field coils knows the impracticability of counting the turns as they go. There are various reasons for this; the shape of the coil for one and the great number of turns for another. The method used by the writer was as follows:

The head of a ¾-in. by 12-in machine bolt was cut off. This headless bolt was securely locked in a lathe chuck and the coil form placed on it as on a shaft. The form was locked on its shaft by means of a ¾-in. hexagon nut. Next, a center was drilled into the end of the bolt. A revolution counter was then clamped in the tool post, horizontally, so that its contact point fitted snugly into the center of the bolt. This arrangement registered every turn of the form, allowing the winding to be done at greater speed than would otherwise have been possible, with a consequent saving of time on the job.

MAURICE M. CLEMENT.
Long Beach, Calif.



The revolution counter was held in the tool post of the lathe, with the end against the shaft supporting the coil form, to record the number of turns wound on the coil.

Composition and Ageing of Insulating Varnishes

IT HAS been shown that during the natural oxidation of oil varnishes for a period of time the resistance of a varnished insulation may decrease. This decrease in resistance is the result of formation, by oxidation, of low-resistance materials, chiefly acids of lower molecular weight which are volatile and form conducting solutions with water.

A number of factors influence the amount of these low-resistance materials very markedly and in making an examination of varnishes for insulating purposes the test must be made under fixed conditions, in order to obtain comparative values. The results to be described were obtained by taking cotton strips, standard insulating tape, and dipping unit lengths of this tape (one meter) into the varnish and allowing them to drain. Under these conditions the average insulating varnish has become air dry in 48 hr. and some of them in 24 hr., as shown by the stoppage of weight loss due to evaporation and the physical condition of the tape. The various varnishes yield a varying quantity of varnish gum depending on the nature of the varnish. In carrying out the examination for acidity a check is, therefore, obtained on the rate of drying and the body of the varnish.

Enough strips were prepared so that a sample could be taken on successive days over a period of time. Certain of the samples were exposed to the air at normal temperatures while a corresponding number of samples were baked at 100 deg. C. (212 deg. F.) in order to obtain a comparison of the effects produced.

Inspection of the results showed two things. First, that the amount of acidity formed is really a function of the time, increasing as the oxidation progresses. Other results indicate that for most varnishes the oxidation increases up to 96 hr., but after that it is practically complete, where we have a thin film. The second fact shown is that the values are really characteristic for the particular varnish. While the quantity increases with time, the order of the different samples remains essentially the same so that, for purposes of comparison, a 48-hr. test period is as good as a 96-hr. period.

The table of results was obtained on especially-prepared samples of varnishes. There were over 30 samples of known composition and a large number of tests were made so that the average results quoted here give a reasonably accurate picture of the true relations. The values given under "oven dried" were obtained by baking for a short time (4-5 hours) at 95 deg. C. Continued baking would of course finally remove the greater portion of the low-resistance materials. The initial effect is to hasten their formation.

Inspection of these results shows that so far as the oils are concerned: (1) Linseed oil varnishes are the most acid. (2) Chinawood oil varnishes develop less acidity than the linseed oil varnishes. (3) With the same oil the acidity developed is greater, the greater the percentage of oil.

Research Department, H. C. P. WEBER.
Westinghouse Electric & Mfg. Co.,
East Pittsburgh, Pa.

Results of Tests of Insulating Varnish Showing Acid Content That Forms Conducting Solutions With Water

MATERIAL	PER CENT	AVERAGE PERCENT ACID	
		AIR DRIED	OVEN DRIED
Linseed oil A	80	2.4	2.34
Linseed oil B	80	3.3	3.00
Linseed oil C	80	3.5	3.02
Restrainer D	80	2.5	2.8
Chinawood oil	80	1.5	1.8
Linseed oil	70	1.43	1.7
Linseed oil	50	0.88	1.68

How to Put Odd Bits of Solder Into Usable Form

THE bits of solder which collect about the shop may be saved by melting them up and pouring them in some sort of mold. A simple and inexpensive mold which will give strips of solder of convenient size can be made in a moment from a piece of ordinary tongue-and-groove board, which has a groove about ¼ in. wide and ⅜ to ½ in. deep.

Clamp one or more of these boards, which may be three feet long or any convenient length, approximately level in a vise. The sides of the grooves should be greased or oiled in order to prevent the solder from sticking in the groove after it cools. Press a small piece of putty or clay on each end of the groove so as to form a sort of trough. This may then be filled with the molten solder poured out of a ladle. When cold the strips of solder can easily be removed from the groove by turning the board upside down and tapping one end on the bench top. The strips of solder may then be cut into convenient lengths with a pair of pliers.

Oakland, Calif. S. H. SAMUELS.

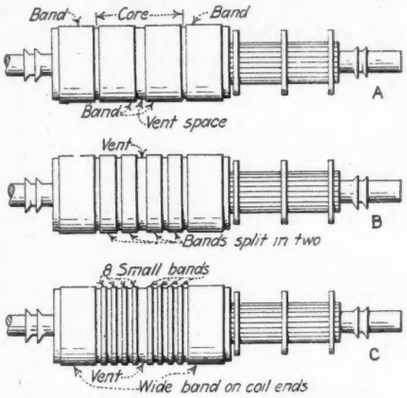
Eddy Currents Cause of Trouble with Armature Bands

SOME time ago I was called upon to repair an armature on which the bands had loosened up and the coils been thrown out of the slots, damaging the fields so that they, too, had to be rewound. This armature belonged to a 25-kw., 2-pole, 110-volt, turbine-generator which was used on a boat. After the armature was rewound it was banded with No. 12 steel banding wire, as shown in (A) of the illustration. We made two bands across the core, one on each side of the vent space, with the wide band on each end to hold the ends of the coils down. After the fields were rewound the generator was assembled and worked satisfactorily, although we had to excite the fields, as they had lost their residual magnetism.

Nothing more was heard of the job until the management of the boat line told us one day that the bands had come off again. Upon asking the engineer how the generator behaved he said that it had failed to build up and that he had run the turbine about 1,000 r.p.m. overspeed in trying to bring the voltage up to normal. Consequently, we blamed the high speed as the cause of the bands breaking.

The armature was again taken out and the coils retaped and put back into the slots. The fields had to be rewound again because the loose wire had ripped them to pieces. After the armature was finished it was banded as shown in (B), using more clips to insure against breaking the bands at high speed, and also splitting the bands in two, as shown. After running three days three of the bands came off again, leaving one on the core. In none of these instances had the end bands let loose.

After looking the remaining band over carefully we noticed that all of the solder was melted off the clips and wire; so we came to the conclusion that the bands were being heated up by eddy currents which were induced in them. The temperature was thus raised high enough to melt the half-and-half solder which had been used on all of these jobs.



Wide bands, as in A and B, heated up sufficiently to melt the solder and come off. When they were replaced with eight narrow bands, C, this trouble was eliminated.

As the coils had not been damaged this time, eight small bands of about five turns each were put on, as shown in (C), and the armature has operated satisfactorily ever since.

Milwaukee, Wis. E. KALEN.

Turning an Ice Machine Shaft Without Removing It

A LARGE brewery with three ice machines has a complete machine shop and some good mechanics, but this particular repair job required more equipment than they had and so a contract machine shop was called on for expert assistance. The split-type flywheel of this machine weighed six tons and was driven by a 1¼-in. key. The bolts at the hub had not been kept tight enough and the wheel had been working on the shaft for years, although the "engineer" had not noticed this because the wheel always went around and it did not shift endwise. Under the new regime, the "mysterious pound" in the machine had been located and found to be past correction; so the wheel was taken off.

Inspection showed that it would be best to get a new wheel and have it fit the shaft size after the latter was turned off approximately ⅛ in. below the original diameter of 10 in. The factory was given an order for a new wheel with the information that the shaft size would be forthcoming. It was decided to turn the shaft in place. A survey showed the shop man that a length of 16 in. was to be turned on a section over the pit and between an engine main bearing and the outboard bearing.

The plan that was adopted was to suspend a slide ahead of the shaft, in this section, and turn with a tool held in a carriage on that slide. In this case, the slide was the cross-rail from an 18-in. planer in the machine shop. This cross-rail was 30 in. long over all and the head with its toolpost provided means for moving and adjusting the tool both ways. A feed of 24 in. was possible, which was enough to get the desired position without interfering with the mode of suspension employed.

A pattern was made and two castings secured, which were placed on the two adjacent pillow blocks (from which the caps had been temporarily removed), after each casting had been drilled to pass over the two studs. At the outboard bearing, the cap was left off and the nuts screwed down tightly on the cast-iron bracket. At the main bearing, the casting was thinned down so the cap, when replaced, could be bolted to the proper fit on the shaft; afterwards, thin wedges were driven in to steady the bracket.

These brackets were made with a drop, or offset, that made a floor some distance below the horizontal center of the shaft upon which the cross rail was laid and to which it was bolted. This position was such that the tools would come the proper height for cutting the shaft.

The weight of the shaft was sufficient to keep it in place against the light cut, even if there had not been the one cap over it. The cross rail had been located on the side where the shaft ran "down" and against the top of the tool. For actual cutting, a speed of 20 r.p.m. was obtained by throttling the engine.

It took all of one day to do the actual turning of this shaft. The roughing cuts were used to check the parallelism of tool travel with the shaft's axis; before the final cut was taken, this had to be assured, because there could be no filing of the shaft to "touch up" when there was that keyway to bump the file every time around.

When completed, it was a first-class job and the cost was but a fraction of what it would have been had it been necessary to strip the machine and remove the shaft to a shop with lathes big enough to turn it.

Instead of sending the ice machine makers the size of the shaft in inches, a gage was sent to them, carefully protected in a box on its thousand-mile trip to Milwaukee, Wis. This gage was made of a piece of ½-in. by 2-in. black steel, forged half round, and fitted over the newly turned shaft—it was thought best to do the measuring this way and let the makers transfer the size as they chose.

In fitting this gage to the shaft, it was carefully filed out between the rounded points until it would pass over the shaft without feeling it touch, but so that it could be felt touching when a piece of newspaper was held on one side. For the final fit, the gage was immersed for 20 min. in a tub of water kept at 80 deg. F. by turning steam into it. The temperature at the time of fit and the method of gaging the feel of the fit were given to the builders. The wheel, when it was put in place, was so perfect a fit that the care spent in the work was fully justified.

DONALD A. HAMPSON.

Plant Superintendent,
Morgans & Wilcox Mfg. Co.,
Middletown, N. Y.

What Voltage Should Be Used for Testing the Insulation of Motors?

THE question of high-potential testing of motors and generators has always been a bone of contention. N. L. Rea, engineer in the Contract Service Department of the General Electric Company, in discussing this question in *Power*, points out that some operating engineers believe in periodic high-potential tests. In this connection he expressed his opinion as follows: They claim that they can thereby locate faults and make needed repairs without serious damage or delays. Others claim that every time the insulation on any equipment is overstrained part of its life is taken away. I am inclined to the latter belief. How much the life is reduced cannot, of course, be determined, but it is certain that a heavy strain does not do the insulation any good.

We ordinarily think of double voltage or higher when we speak of high-potential testing. This is all right for the new machines in the factory, which are clean and dry. It is altogether a different proposition with old machines. Many an old machine with years of satisfactory service ahead would have to be completely rewound after a standard A. I. E. E. high-potential test.

It is my belief that an old machine that has been thoroughly cleaned and varnished, should have a potential test to ground of the normal voltage. This would be about 25 per cent higher than the strains under ordinary operating conditions. This test can also be used on machines that are under suspicion, say after a heavy short-circuit on the generator cables or switches, a runaway, a bad shot in synchronizing or the like.

If a high-potential test is made, be sure the testing transformer is large enough. Many a man has fooled himself and others by using a 200-watt instrument transformer to give a big armature a high-potential test and multiplied the low-voltage reading by the name-plate ratio. If you want to kid yourself, this is a nice and safe way to do it. A large armature is a first-class condenser, and the charging current may require 20, 30, or even 50 kva.

When in doubt it is safer to get advice from the manufacturers of the machines in question. They are always glad to give advice and suggestions.

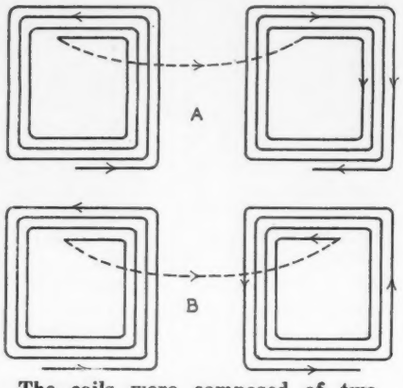
The use of a spark gap to measure the voltage should be avoided if possible. It's a good idea to use a spark gap as a safety valve, but it is better to use a small transformer across the high side of the testing transformer and read the voltage from the low side of this small transformer. This discharge of the spark gap may set up oscillation and cause a higher voltage than desired or indicated.

The use of kenotrons to rectify alternating current to direct current gives a means of high-potential testing with a very small amount of electrical energy.

This method, however, is in an experimental stage, and alternating current will probably be available and used in the majority of cases for some time to come.

Improper Connection of Motor Field Winding

A STANDARD electric railway car motor had been temporarily applied to a hoisting job and on being retired from this duty it was overhauled on account of being oil-soaked. After it was overhauled it looked good but it would not run. The usual tests were applied for open-circuits, grounds and short-circuits; none could be found.



The coils were composed of two sections which were connected so that they bucked each other, A. The correct connection is at B.

The armature was then removed from the frame, the frame closed, current passed through the field coils and the polepieces tested for polarity with a compass. The compass gave indications no one could understand. On trying the polepieces with an iron bolt, the pull on the bolt was suspiciously weak although full-load current was being passed through the field coils. This suggested that all of the coils were short-circuited —which was an unlikely condition.

The machine was sent to a repair shop to be investigated and its action related to the investigator. Full-load current was passed through the field circuit and the voltage drop taken on each coil. All of the drops were the same and about what was to be expected in value. As this eliminated the short-circuit idea, all of the insulation was ripped off the coils in order to inspect them.

The inspection disclosed the trouble. Each coil was composed of two similar sections of flat copper insulated with asbestos. Section (2) was to be placed on top of section (1), the inside ends then being clipped together. In the illustration (A) shows how the sections were connected, the two sections being shown alongside each other. By following the arrow heads it will be seen that current entering through either outside lead will circulate around the two sections in opposite directions. On turning the second section over before laying it upon the first section is produced the condition indicated in (B). It will be seen that current entering the free end of either section, will circulate around both in the same direction.

Brooklyn, N. Y. J. A. HORTON.

Changing Two-Phase Motor for Three-Phase Operation

ONE of the small townships in Michigan recently changed the generating equipment from two phase to three phase and in changing over motors in local plants to meet the new line conditions some interesting situations were encountered.

One case involved a 2-hp., 220-volt, two-phase, 5-amp., 1,800-r.p.m., four-pole, sixty-cycle motor that had thirty-two slots and coils, each coil consisting of forty-two turns of one No. 18 d.c.c. wire, pitch 1-and-8, connected two-parallel.

Now, thirty-two coils will give a balanced, equal coil grouping for four poles, two phase, as there are sixteen coils per phase, or $32 \div (2 \times 4) = 4$ coils in series per pole-phase group; but for three phase four poles, the grouping will be unequal and the coils per phase will be unequal, as $32 \div 3 = 11$ plus 11 plus 10 coils per phase, which will not do for a stator winding.

Then in order to obtain an equal number of coils per phase, two coils will have to be killed or left out ,making a total of thirty coils, which will necessitate calculating the three-phase winding to compensate for the lost turns.

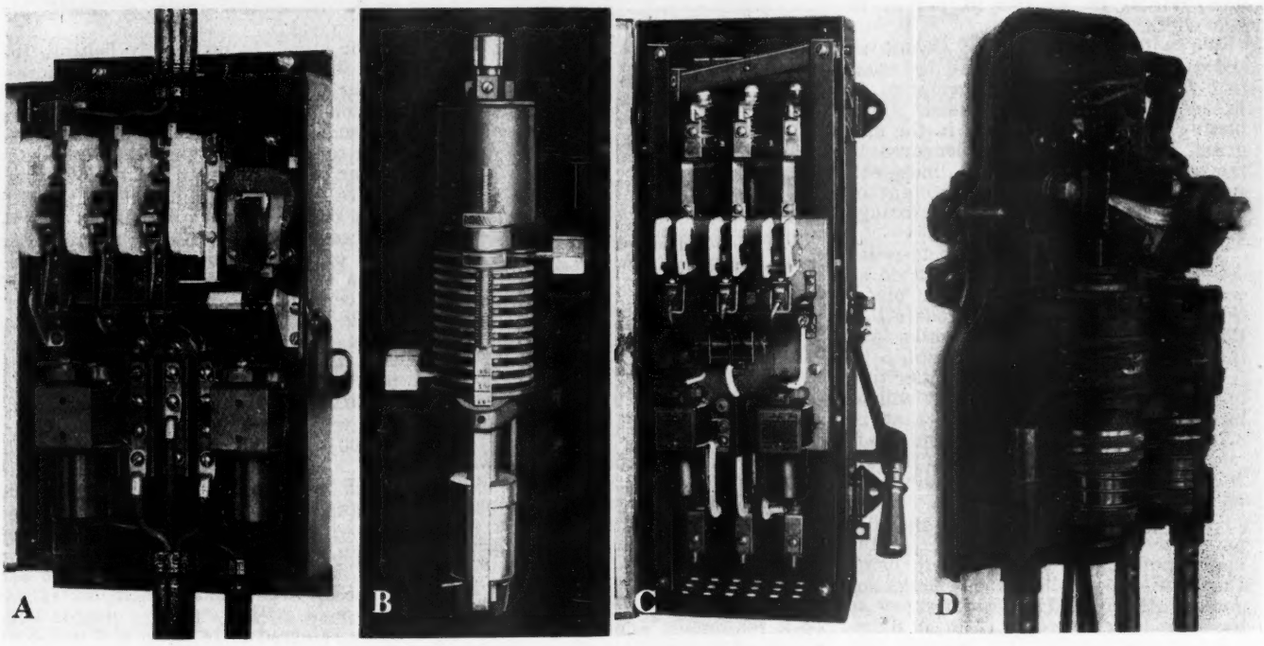
The series-delta, three-phase line voltage, using the same turns per coil, would be $[(2 \times 2 \times 220) \div 3] \times 1.06 =$ 310 volts, but a series-star connection is preferable in this case, as there will be unequal grouping and two coils left out. Then the series-star line voltage would be $310 \times 1.73 = 536$ volts. To develop 536 volts, there would be $(32 \times 42) \div 3 = 448$ turns per phase, and for a three-phase, 220-volt, series-star connection there would be required $220 \div 536 = X \div 448$ turns per phase; or $(220 \times 448) \div 536 = 183$ turns, and with ten coils per phase there would be $183 \div 10 = 18.3$ or eighteen turns per coil. By figuring the turns per phase as above, the turns lost in the two coils are compensated for.

With 5 amp. per terminal and a two-parallel connection the current per coil was 2½ amp. One No. 18 wire has an area of 1,624 circ. mil, and at 2½ amp. there were $1,624 \div 2.5 = 650$ circ. mil, per amp. The three-phase, 220-volt, 2-hp. current rating would be approximately 6 amp. and with a series-star connection this would also be the current per coil and with 650 circ. mil per amp. there would be required $650 \times 6 = 3,900$ circ. mil. The wire size closest to this is No. 14, with 4,106 circ. mil. Trying a slot full of thirty-six No. 14 silk-covered-and-enameled wires it was found that there was enough room for this winding.

The three-phase winding then consisted of thirty coils, each coil containing eighteen turns of one No. 14 silk-covered-and-enameled wire, pitch 1-and-8, connected series-star, ten coils per phase with six groups of two coils and six groups of three coils arranged as follows: (2-3-2) (3-2-2) (3-3-2) (3-2-3).

After winding and testing the motor ran satisfactorily and was evenly balanced in all three phases.

Wilkinsburg, Pa. A. C. ROE.



What Happens During Single Phasing

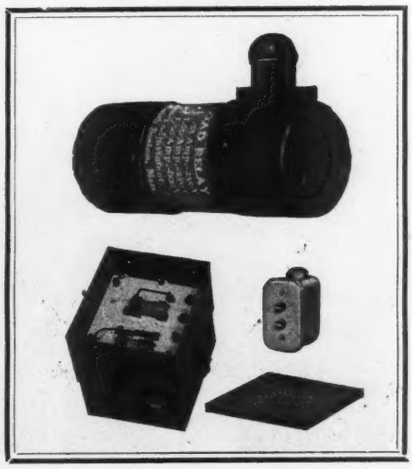
(*Continued from page 187*)

No-voltage releases do not protect against single-phase operation. For even though one wire is opened, the motor itself will maintain voltage on that wire, so that failure of *voltage* of any phase does not occur if a motor is connected to it. Instances are on record where one wire of a factory supply has been interrupted at the source, and the motors of the plant kept that wire energized so that there was always three-phase power around the plant as long as some motors were running. Motors could be started three-phase; all three voltages were present, although badly unbalanced; and no one knew that one phase was open until the motors began to burn out. If all the motors in the plant had been shut down at the same time, the third wire would have lost its potential and the motors would not have started again, but as long as some motors were running, they acted as phase converters and supplied the idle wire.

EDITOR'S NOTE:—Special acknowledgment is made to the following companies for their kindness in furnishing information and some of the illustrations accompanying this article: The Automatic Reclosing Circuit Breaker Co., Columbus, Ohio; Allen-Bradley Company, Milwaukee, Wis.; Condit Electrical Manufacturing Company, South Boston, Mass.; The Cutler-Hammer Manufacturing Co., Milwaukee, Wis.; The Electric Controller & Manufacturing Co., Cleveland, Ohio; Federal Electric Company, Chicago, Ill.; General Electric Company, Schenectady, N. Y.; Industrial Controller Company, Milwaukee, Wis.; Monitor Controller Co., Baltimore, Md.; The Rowan Controller Co., Baltimore, Md.; Sundh Electric Co., Inc., Newark, N. J.; Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Time element overload relays are another form of protection used to prevent single phasing.

Such relays may be set to trip at full-load, motor line current and yet take care of momentary overloads without tripping. At *A* is shown the across-the-line starter made by the Industrial Controller Company of Milwaukee, Wis. The inverse time element relays are located in the lower left- and lower right-hand corners of the starter. The inverse-time element is secured by means of oil dashpots. At *B* is shown the time element relay used by the Monitor Controller Company of Baltimore, Md., in its larger starters. The time element in this relay is also secured by means of an oil dashpot. *C* is a semi-automatic resistance starter made by the Allen-Bradley Company of Milwaukee, Wis. The time element relays used for overload and lost-phase protection are shown at the lower left- and lower right-hand corners of the compensator. An oil dashpot is also used in this relay to give the time element. *D* shows the time element relay used by the Electric Controller & Mfg. Company of Cleveland, Ohio, in their larger starters. This relay has two coils and two dashpots; one for each phase.



Single-phase and overload protection device made by the Condit Electrical Mfg. Company of South Boston, Mass.

In the lower illustration is shown a motor starter which is arranged for thermal relays. The thermal relay, shown in the upper illustration, has a thermal element which is acted upon by the motor line current and in case of abnormal load will break a control contact, thus stopping the motor.

Short-Center Belt Drives

(*Continued from page 172*)

per inch of belt width should be between 32½ and 84½ lb. when running at the calculated belt speed of 4,000 ft. per min. for this drive. We have a single-stage compressor doing intermittent duty; so we may take a value about halfway between these two extremes as explained in note 4 of Table I. We will choose a value of 50 lb. per in. of belt width. Our driving pulley diameter of 13½ in. is about the minimum recommended for double-ply belting; hence we could use either single or double belting with about equal advantage.

If we use standard double-ply belting, the belt width will be equal to (horsepower$\times$33,000)$\div$(belt speed$\times$effective tension per in. width)=(7.2$\times$33,000)$\div$(4,010$\times$50)=1.2 in.

This is a ridiculously narrow belt for double-ply belting. We will use a single-ply belt of double the width worked at 25 lb. effective tension per inch of width. Since a 2.4 in. belt is an odd size, we will use one 2½-in. wide. Our effective pull will be equal to the belt width times the effective pull equals 2.4$\times$25=60 lb. This gives an effective tension per inch of belt width of 24 lb.

Referring to Table I and notes 8, 9, 10 and 11 under it, we find that for a belt speed of 4,000 ft. per min. the slack-side tension should be somewhere between 60 and 30 per cent of the effective tension. Since this is a single-stage compressor and will run intermittently (see note 9), we will choose a value of 59$\times$1.5=68 per cent. Hence our static or slack-side tension will be 68 per cent of the effective tension or

0.68×60=41 lb., or 16.5 lb. per in. of belt width.

We will now make our layout as shown in Fig. 6. A_1B_1 will be equal to C_1D_1 and they are both equal to 41 lb. as we have just determined. Completing the graph as shown in the diagram, we find that O_2E_1 measured to the same scale as the other lines, will equal 58.75 lb. This is the weight of the idler and that part of the fittings supported thereby.

The rods *RO* are made of cold-rolled steel, or in this case pipe would do as well. Suppose a computation places the total weight of the two rods at 7.5 lb. The shaft for the idler pulley and the connecting fittings will weigh 5 lb.

The weight other than the idler pulley to be supported by the belt will be half the weight of the rods, that is, 3.75 lb. plus the weight of the shaft and fittings (5 lb.) or, a total of 8.75 lb. Hence the net weight of the idler pulley would be 58.75–8.75=50 lb.

It would be best to make this idler pulley about the same diameter as the motor pulley, but since we are using single belt on a pulley large enough for double belt, it will be satisfactory to have the idler 10 in. or 12 in. in diameter or even smaller if a suitable pattern is in stock.

Suppose that instead of the direct-current motor used in the previous example we wish to use a squirrel-cage induction motor and start it across the line so as to use a cheap form of automatic starter for starting and stopping the compressor in maintaining an approximately constant air pressure. Let us see how this will affect our layout.

Our load is 7.2 hp. We must use either a 5-hp. or 7½-hp. motor, since standard motors are not available in intermediate sizes. A normally-rated 5-hp. motor (40-deg. temp. rise) would scarcely carry this load unless we could be certain that conditions would be such that the motor would operate only a very few minutes in each hour. Even then if we decided to use a 5-hp. motor, we would be obliged to use a thermal relay, or some similar device to protect the motor, if due to a leak in the piping, the compressor were called upon to operate more or less continuously in order to keep the pressure up in the receiver. We will use a standard 7½-hp. motor. We know that it will stop and start very many times per day.

First we make a complete computation for running conditions which will be identical with that given in the previous example. Next, we must make a complete computation for starting conditions. The manufacturer informs us that his motor will exert a breakdown or maximum running torque equal to 250 per cent of full-load torque. It is necessary when obtaining this information from the manufacturer, to make it plain that you desire not the minimum starting torque for the type of motor, but the actual starting torque for the particular size and speed of motor in question. If the motor is likely to be operated at higher than nameplate voltage, it is necessary to increase the manufacturer's figure for starting torque by 2 per cent for each 1 per cent of overvoltage under which the motor is likely to start. This torque will be exerted while the motor is starting as it passes through about 75 per cent of full-load speed, that is, at a belt speed of approximately 3,000 ft. per minute.

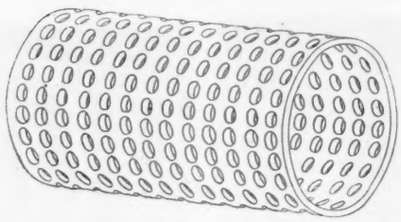


Fig. 7—Method of lubricating the idler pulley.

If a tube, drilled full of holes as shown, is interposed between the idler bore and the shaft, the holes will soon fill with grease from the grease cup located as shown in Fig. 1, and will make it necessary to lubricate the idler only at long intervals.

From our previous calculation we found that the effective pull was 60 lb.; hence for this design we must make a design for 250 per cent of 60 lb. which equals 150 lb. effective pull at 3,000 ft. per min.

From Table I, and notes 2, 3 and 4 following it, we decide that 60 lb. will be a reasonably effective pull per inch width of standard double-ply belt. So narrow a double belt as we are considering would probably be light double-ply rather than standard double-ply. This, according to Table I, would call for a stress of 75 per cent×60=45 lb. per inch of width.

Our motor pulley diameter will allow us to use either single- or double-ply belt.

For standard double-ply belting, the belt width would be equal to (horsepower×33,000)÷(belt speed×effective tension per inch of belt width). Since the motor will exert a maximum running torque of 250 per cent, the horsepower used will be 7.5×2.5=18.75. Reference to Table I will show that with light double-ply belt we should use 75 per cent of the effective tension per inch of belt width that we would use for a standard, double-ply belt and 50 per cent of the effective tension for a single-ply belt. Hence, substituting these values in the formula we find that the width for a light double-ply belt will be (18.75×33,000)÷(3,000×60×0.75)=4.6 in. For a single-ply belt, the width will be equal to (18.75×33,000)÷(3,000 × 60 × 0.50) = 6.87 in. For a standard double-ply belt, the width will be (18.75×33,000)÷(3,000×60×1.0)=3.44 in. It is likely that the width of face on our compressor pulley is less than 7 in. If this is the case, there is no alternative but to use a 4.5-in. light double belt or, if we choose, a 3.5-in. standard double belt.

As referred to in notes 6, 7 and 8 of Table I, we should use column C_1 of Table I in determining the slack-side tension. Referring to this column, we find that the slack-side tension for a belt speed of 4,000 ft. per min. should be 25 per cent of the effective pull. Our effective pull we have just found to be 150 lb. Hence our slack-side tension will be 0.25×150=37.5 lb., say 38 lb.

Now for our layout. We can use the same layout as before in Fig. 6. We must, however, use a different scale in measuring it—a scale of 38/33 times that used previously. Completing the graph we find that the necessary weight of idler, shaft fittings and half the rods will be 54 lb. The net weight of the pulley necessary would then be 45.25 lb.

In this case we see that both belt size and pulley weight must be determined from starting conditions. If an example had been selected with ex-

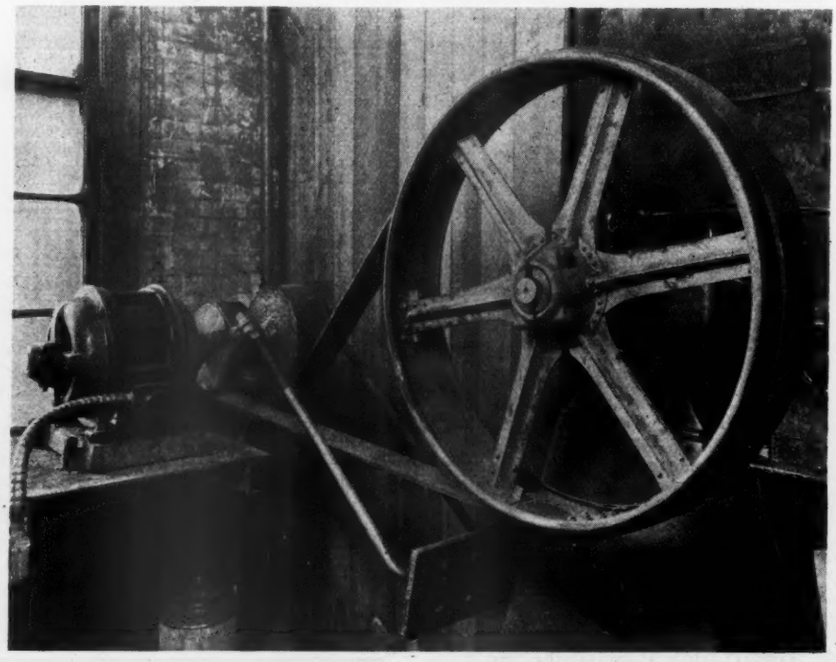


Fig. 8—Short-center drives are just as effective on small units as on the larger drives.

A 3½-hp., two-speed, 600-1200-r.p.m., squirrel-cage induction motor drives the foundry fan shown at the right of the illustration through a 4-in. belt. Both the idler and motor pulleys are 12 in. in diameter, while the driven pulley is 36 in. in diameter. To secure the most effective weight of the idler, which would give the proper belt tension for the load carried and still not unnecessarily overload the belt, it was necessary to use a wooden pulley for the idler.

tremely high belt speed, we would have found that the size of belt was determined by the starting conditions and the pulley weight by the running conditions.

A simple and reliable method of lubricating the idler pulley is essential. Grease is generally used for this purpose. An excellent method is to drill the idler shaft, put a grease cup on the end as shown in Fig. 1, and drill several holes, say three, at three points along the shaft. If a tube drilled full of holes, as shown in Fig. 7 is interposed between the idler bore and the shaft, the holes will soon fill with grease, and will make it necessary to lubricate the idler only at long intervals.

On small fan drives and the like where the loads are less than 50 hp., the required weight of idler frequently figures out so low that a cast-iron pulley of suitable diameter and width cannot be designed. In such a case a paper or wood pulley as shown in Fig. 8, will generally solve the problem at lower cost even than a cast-iron pulley. *Order it without keyway* for such pulleys are ordinarily stocked with keyways, and the keyway offers a path for the grease to work out without doing its duty.

Do not make idler pulleys too small. A small idler pulley will, it is true, allow a slight increase in arc of belt contact, but the sharp reverse bend is hard on the belt. The idler pulley should be at least as large as the driving pulley. Where the driving pulley is near the lower limit for thickness of belt, the idler pulley may well be 10 to 20 per cent larger, even at some sacrifice of the arc of contact of the belt on the driving pulley.

I need hardly mention that in making the original layout to determine relative location of motor pulley, angle of hinge rods, size of idler pulley, and the like, it is well to sketch in the idler pulley at the position which it will occupy after taking up on the belt. If the idler pulley will strike the driving or driven pulley in this position, do not let it go with the idea that the operator can adjust the reach rod length as the belt stretches. Idler pulleys jump from time to time as the motor starts, especially when the starter is out of order and the electrician starts the motor on the line "just once" to avoid an objectionable delay. Then, if a belt lacing comes just right, or if the idler pulley interferes by only ⅛ in. or so, or if several other "ifs" happen, something will bend or break, generally the motor shaft. Such a layout may usually be made entirely satisfactory by moving the motor back a few inches, or changing the inclination of the hinge rods, or both.

If you change the inclination of the hinge rods after you have determined the weight of the required pulley, make a new layout, and determine that weight once more. Any change in the inclination of the hinge rods will change the required weight as will be evident from a consideration of the graphic layout.

Whenever possible use a glued or cemented joint in the belt. A laced belt has a way of slipping as the laces pass the driving pulley.

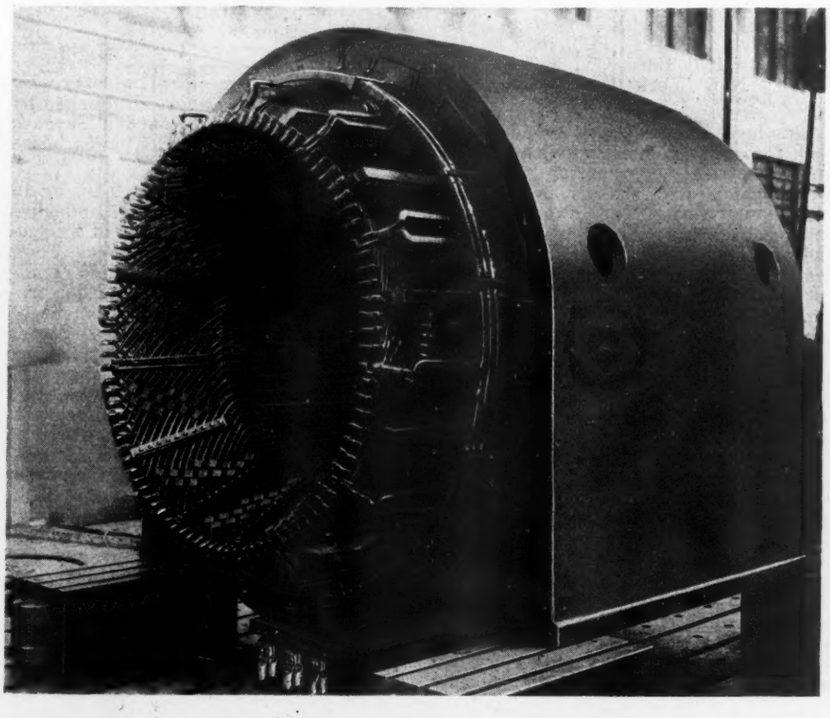


Fig. 9—The method of tying the end turns together can be seen in this illustration.

This is in addition to the method of bracing described in Fig. 1. This machine is much smaller than those shown in Figs. 1 and 4.

Turbo-Generator Windings

(*Continued from page 181*)

In this winding, there are six pole-phase groups, each group having six coils. A front pitch of 1-and-13 is used, and a back pitch of 1-and-14 is required. Let the A phase start with the terminal T_1 which is connected to the bottom conductor in slot *1*. In this diagram, the bottom conductor in a slot is shown by a short line while the top conductor in a slot is shown by a long line. The rear end of the bottom conductor in slot *1* is connected to the rear end of the top conductor in slot *14*. The front end of the top conductor in slot *14* is connected to the front end of the bottom conductor in slot *2*. The winding then continues through this pole-phase group through slots *15*, *3*, *16*, *4*, *17*, *5*, *18*, *6* and *19*. This pole-phase group ends at the top conductor in slot *19*; the front end of this conductor is then connected by means of the jumper *J* to the ring *P*, which is connected by means of the jumper *L* to the front end of the top conductor in slot *1*. This starts the second pole-phase group for the A phase. The second pole-phase group ends in the bottom conductor in slot *19*, which is connected by means of the jumper *D* to the star ring *S*. The remaining two phases are connected in a manner similar to the first.

The diagram shown in Fig. 6 is the same as would be given to the winder in the shop. If this machine were to be stripped, the coils reinsulated and the old connection used again, the rings and jumpers should be marked as shown by the letters, for otherwise it would be difficult to fit together the 17 different-sized connections and rings. By marking the slots, leads, and end connectors from the coils to the rings, there will be no time lost in sorting out the various end connectors and trying to find where they fit.

Practical Books
For Your Personal Library

Every man who aspires to larger responsibilities should build up a professional library. Copies of these books may be obtained from the publishers mentioned.

Electrical Drafting and Design—By Calvin C. Bishop. Published by McGraw-Hill Book Co., 370 Seventh Ave., New York City, 161 pages, price $2.00.

In the preface of this book the author states that it was his purpose to bridge the gap between the usual course in mechanical drafting as taught in technical and vocational schools and the work a young man is required to do in the office of an engineer, a contractor or a power company. Numerous examples of wiring layouts are presented, with data forms giving dimensions of apparatus and other information needed without going to the trouble of obtaining many catalogs and data sheets for this purpose. The chapter headings are as follows: General instructions for mechanical and electrical drafting; electrical symbols and their use; generator and feeder panel; three-phase panel; outdoor substation; laying out wiring; residence wiring; artificial illumination; and tables and charts.

* * * *

Practical Mathematical Analysis—By H. Von Sanden. Published by E. P. Dutton & Co., New York City, 194 pages, price $4.50.

This book is written for those who have a thorough groundwork in mathematics and presents mathematical methods by which the solution of any given problem may be evaluated in a numerical form. The following subjects are treated: The slide rule; the calculating machine; rational integral functions and their extrapolation; numerical differentiation and integration; mechanical quadrature; integration and differentiation by graphics; analytical approximation to empirical functions; solution of equations, linear, transcendental and non-linear; integration, graphical and numerical, or ordinary differential equations of the first, second, and higher orders.

* * * *

Eye Hazards in Industrial Occupations—By Louis Resnick and Lewis H. Carris. Published by the National Committee for the Prevention of Blindness, Inc., 130 East Twenty-Second Street, New York City, 250 pages, 60 illustrations. Price, paper bound with linen backing $1.50; fabrikoid bound, $2.50.

This book is a compilation of a large number of methods and applications of various devices for the protection of the eye from injuries by flying objects, chemicals and a large number of other more uncommon hazards. A chapter is devoted to a discussion of the necessity, value and problems incidental to industrial lighting. Some of the topics discussed in the various chapters are: Nature and causes of eye injuries; eliminating eye hazards; industrial accidents and means for their prevention, first aid treatment for eye injuries; correction of defective vision; diseases affecting the eye; industrial lighting; education as to safety; the safety movement and its effect on the eye hazards in industrial occupations.

An appendix gives industrial poisons presenting hazards to the eye, and a goggle code of the American Steel and Wire Co., which shows all the occupations where goggles are compulsory or desirable in various departments.

* * * *

Substation Operation—By Edwin Kurtz. Published by the McGraw-Hill Book Co., 370 Seventh Ave., New York City, 252 pages, price $2.50.

This book has been written to help the practical operator and his assistants to obtain a knowledge of the principles as well as the methods of substation operation. It deals with substation layout and wiring and gives details of all the equipment that is used in the modern power substation. Three chapters, which occupy practically one-half the book, will be found very useful for the practical man. These chapters give operating procedure in connection with substation work, instructions on hunting troubles and correcting them, together with details on accident prevention. Illustrations show views in different types of substations and the procedure recorded follows the best practice of operating companies. For those who are required to train substation operators and are responsible for inspection and maintenance, this book will be a useful guide and handy reference.

* * * *

Industrial Electricity — Part 1 — By Chester L. Dawes. Published by the McGraw-Hill Book Co., 370 Seventh Ave., New York City, 363 pages, price $2.25.

This book has been written as a textbook for use in connection with elementary electrical engineering, both in high schools and schools preparatory for college work. The first volume is devoted to direct current, while the second volume, under preparation, will deal with alternating current. Throughout the text the author explains in simple language the principles underlying electrical engineering and electrical equipment and gives a bird's-eye view of electrical problems to those who are beginning a study of the subject. While the text deals with underlying principles of circuits and machine operation, illustrated problems and details of equipment are given in such practical form that the student can apply the fundamental discussions to practical work. The subjects discussed in this book are: Magnets and magnetism; electro-magnetism; resistance; Ohm's law and the electric circuit; battery electromotive forces; primary and secondary batteries; storage batteries; electrical instruments and electrical measurements; the magnetic circuit; electrostatics; the generator; generator characteristics; the motor; and losses in efficiency and operation.

* * * *

Practical Radio—By James A. Moyer and John F. Wostrel. Published by McGraw-Hill Book Co., 370 Seventh Avenue, New York City, 244 pages, illustrated, price $1.75.

This book describes practically all of the successful circuits that are now used in radio receivers. It gives details on their construction and operation and how to test and repair them. Many wiring diagrams are used and information is given covering the construction and features of the essential parts of a radio circuit. The subjects covered are as follows: The antenna, radio electricity explained, telephone receivers and crystal receiving sets, vacuum tube receiving sets, sources of electricity for vacuum tubes, audio-frequency amplification, radio-frequency amplification, selection, operation and care of radio receiving sets, radio telephone and telegraph transmission, construction and testing of receiving instruments, common troubles and their remedies, the future of radio.

* * * *

American Society of Heating and Ventilating Engineers Guide—Published by the American Society of Heating and Ventilating Engineers, 29 W. 39th St., New York City, 445 pages, price $3.00.

This book contains reference and design data useful in the planning and construction of modern heating and ventilation installations. Material has been taken largely from the Society's Transactions, investigations by its research laboratory and the practice of its members. With this information is presented a catalog and reference-data section containing essential and reliable facts concerning heating and ventilating equipment. The book contains a mass of tabulated information, diagrams and charts. The heating section includes 161 pages and the ventilating section, 63 pages. This guide will be found very useful by those who have to lay out and install heating and ventilating systems.

* * * *

Engineering in American Industry—By Conrad Newton Lauer. Published by McGraw-Hill Book Co., 370 Seventh Ave., New York City, 94 pages, price $2.50.

This book is published in 9 in. by 12 in. size and for the most part embodies material delivered in lectures at Princeton University under the Cyrus Fogg Bracket lectureship in applied engineering technology. The author reviews the growth and development of manufacturing in the United States and the contributions which engineering has made. The subject matter is profusely illustrated with halftones, line diagrams, maps, curves, and charts. The maps, curves and charts are presented in large size so that the information given can be easily interpreted. Captions under each diagram explain in detail the features which these charts and diagrams are intended to illustrate. There are 61 diagrams and curves presenting statistical information on the material resources and industrial activities in the United States. For those who have occasion to use statistical information of this sort the book will be invaluable.

Trade Literature
You Should Know About

Copies of literature which is described on this page can be obtained by writing to the manufacturer whose name and address are mentioned. It is always advisable to state the name and number of bulletin or catalog desired, as given in these columns.

Hart Manufacturing Company, Hartford, Conn.—A 64-page booklet, pocket size, entitled "Diamond H Remote Control Switches," describes the various types of multi-circuit, no-voltage release and tank switches as well as relays and solenoid devices which simplify the control, effect a saving in the first cost of installation and current consumption, and also provide control at various points from a distance without making it necessary to bring the service wires to these points.

Flohr Safety Appliance Manufacturing Company, Buffalo, N. Y.—A folder illustrates and describes the construction and advantages of the Flohr superior saw guards and superior jointer guard for use on woodworking machinery.

Albert and J. M. Anderson Manufacturing Company, 289-305 A Street, Boston, Mass.—Bulletin 35 is a complete catalog of Anderson's "Charging Plugs and Receptacles" for charging storage batteries on electric vehicles, trucks and railway cars.

The Glow Electric Company, 219-21 Walnut Street, Cincinnati, Ohio—A 12-page stock price list gives the new and rebuilt motors and generators as well as other electrical apparatus held in stock by this company.

Rochester Electric Products Corporation, 695 Driving Park Avenue, Rochester, N. Y.—Bulletin 5 describes the Price-Rochester constant potential battery charging system.

Wagner Electric Corporation, St. Louis, Mo.—Bulletin 142 describes the Wagner split-phase, induction motors of the BB type which are built in ratings of 1/6, 1/4, 1/3 and 1/2 hp. for 110 or 220 volts.

Electric Machinery Manufacturing Company, Minneapolis, Minn.—Bulletin 861, entitled, "Synchronous Motors for Pumping," describes and illustrates a number of synchronous motor applications to centrifugal pumping and gives considerable engineering data regarding such applications.

L. B. Allen Company, Inc., 453 North Lincoln Street, Chicago, Ill.—A series of folders describes the Allen non-acid soldering salts, paste, liquids, alumi-flux, alumi-solder and alumi-weld flux, as well as a commutator lubricant. The Allen combination gas-air blow torch soldering and branding tools for use in connection with gas or gasoline are also described, together with the various tips used for different work.

The Yale and Towne Manufacturing Company, Stamford, Conn.—A folder describes the new Yale ball bearing chain block which is made in 11 sizes ranging from ¼ to 20 tons capacity.

Edward T. Moore, 500 Cahill Building, Syracuse, N. Y.—A folder describes the Moore electric power regulator which limits the peak load upon which current cost is based. With this limitation power is billed only for the amount of current which represents a fair average of the daily power consumption instead of on the basis of peak demand.

The Baker R. & L. Company, Cleveland, Ohio—Catalog 29 covers in 52 pages the line of Baker industrial tractors and trucks and discusses the problem of electric material handling and the equipment suitable for it.

Jannette Manufacturing Company, 356-358 West Monroe Street, Chicago, Ill.—A folder entitled, "He Wouldn't Believe It," gives several of the advantages of the Jannette special fractional horsepower motors for use under unusual service conditions.

Philadelphia Gear Works, 1124 Vine Street, Philadelphia, Pa.—A catalog shows the variety of gears manufactured by this company and in addition gives a number of important points to consider in the use of gearing.

Lewellen Manufacturing Company, Columbus, Ind.—A folder entitled, "Put It To Any Test," shows several Lewellen installations under severe service conditions.

The Falk Corporation, Milwaukee, Wis.—Bulletin 35 describes the Falk-Bibby flexible couplings which are made in sizes ranging from 1/3 to 20,000 hp. at 100 r.p.m. This bulletin illustrates the construction, the various features in connection with the operation and gives suggestions on the selection of the proper size and rating as well as special instructions showing how the size of coupling should be determined.

General Electric Company, Schenectady, N. Y.—Bulletin 47640.2 describes and gives applications of the induction, time, over-current relays, Types IA-201, IA-202, IA-205 and IA-206. Details of construction, lists of available range ratings and principles of operation are covered together with other general information. The bulletin is illustrated by photographs, charts and diagrams.

The Roeper Crane and Hoist Works, Reading, Pa.—Catalog 50, containing 16 pages, describes and illustrates the various types of Roeper electric hoists and shows a few of the many applications which can be made of them.

Ingersoll-Rand Company, 11 Broadway, New York City—A circular describes the new air motor hoist which is made in five sizes, with capacities from 500 to 10,000 lb., and also illustrates a number of their applications.

Century Electric Company, 1827 Pine Street, St. Louis, Mo.—A folder entitled, "An Announcement of Extraordinary Importance to Every User of Small Motors," describes the Century wool-yarn system of lubrication for fractional horsepower motors. This motor lubrication was designed for motors in continuous service over long periods of time without re-oiling.

Paul W. Koch and Company, 23 South Wells Street, Chicago, Ill.—A small circular entitled, "The Hole Story," describes the Jiffy adjustable cutter which may be used for cutting holes from ¾ in. to 6 in. in diameter in metal of any gage and up to ¾ in. thickness.

The Service Caster and Truck Company, Albion, Mich.—A 24-page catalog describes this company's line of swivel and rigid casters for trucks. These are provided with ball, Hyatt, or Timken bearings and may be supplied with rubber, fiber or other special treads.

Stephens-Adamson Manufacturing Company, Aurora, Ill.—A booklet entitled, "The Latest Developments in the Design of S-A Unit Carriers," describes the application of high-pressure lubrication and all-steel ball bearings to the carrier roll for belt conveyors.

Crouse-Hinds Company, Syracuse, N. Y.—Folder 13 describes the connectors of the CG series which are made to take rigid or flexible conduit, armored cable or condulets.

General Electric Company, Schenectady, N. Y.—Circular 66028 describes the special temperature indicating panel for generators and motors and the equipment operating on direct-current circuits to indicate at the switchboard the temperature of the various portions of the windings of electrical machinery during operation.

Buffalo Forge Company, Buffalo, N. Y.—A comprehensive review of the use of electric fans for blowing, exhausting, ventilating, cooling and drying is contained in a 16-page illustrated booklet. This covers direct connected units driving small disk or propeller fans, used for ventilating, stoker units, pressure blowers, mill exhausters and electric forge blowers.

Cleveland Armature Works, Inc., 4732-4736 St. Clair Avenue, Cleveland, Ohio—Catalog 315 covers the individual motor driven electric grinders, buffers and polishers, which are made in medium and heavy-duty types.

G. & W. Electric Specialty Company, 7440-42 South Chicago Avenue, Chicago, Ill.—A 16-page booklet, Bulletin 24, illustrates and describes the various G. & W. potheads for protection of cable ends and gives instructions for installing potheads, with other useful information.

Pyott Foundry Company, 28 North Sangamon Street, Chicago, Ill.—A circular describes the Pyott hangers and hanger boxes for duplex, ring or ball bearing lubrication.

The Nichols Lintern Company, 7960 Lorain Avenue, Cleveland, Ohio—A folder describes the Lintern electro magnetic sander for crane runways which is operated by a foot button located in the cab. This folder also il-

lustrates the various types of lightweight signal lanterns for industrial applications.

Smooth-On Manufacturing Company, 570-574 Communipaw Avenue, Jersey City, N. J.—"Smooth-On Handbook" in its twentieth edition is a pocket-size book of 136 pages, which contains descriptions of the various types of Smooth-On cement, shows the purpose of each and in addition, shows by illustrations and descriptions how a number of repairs have been made in industrial plants through the use of Smooth-On. Some applications of Smooth-On floor hardeners and special paints are also included.

Westinghouse Electric and Manufacturing Company, Pittsburgh, Pa.—Circular 1579-C entitled "Micarta Gears and Pinions" gives the advantages claimed for Micarta and similar nonmetallic materials, describes the methods of machining and illustrates cutting tools, gives the physical and mechanical properties and methods for computing the horsepower rating. Two pages of gear data show these computations in tabular form over a wide range.

The Panelyte Company, Trenton, N. J.—Booklet entitled "Panelyte Electrical Insulation" describes the composition and electrical and mechanical characteristics of Panelyte, a hard fibre, dielectric substance which is claimed to be easily drilled, tapped, sawed and polished, although it is not brittle, and is much lighter than stone and similar materials used for switch backing and like purposes.

Shepard Electric Crane and Hoist Company, Montour Falls, N. Y.—A 60-page catalog on, "Floor Operated Electric Hoists," gives a complete discussion of all of the Shepard floor-operated electric equipment This material is arranged in groups with, first, a general description, and then an installation view, which is followed by a portrait view of the hoist. On the next page are given data and price lists and on the page following drawings and dimensions. All the special and extra equipment, which is applicable to all types of machines and must be referred to constantly, is given in the center of the book on green printed stock. Floor-operated equipment is made without trolley (lug or hook suspension), with geared trolley and with motor-driven trolley.

Trico Fuse Manufacturing Company, Milwaukee, Wis.—A folder describes the new line of Trico "Kantark" nonrenewable fuses, which are made in all standard sizes up to 600 amp. rating and are fully approved for both 250 and 600 volts.

Steel City Electric Company, 1207-1223 Columbus Avenue, Pittsburgh, Pa.—Folder describes special universal couplings for conduit work which eliminate the extra threading of pipe ends for ordinary couplings.

Ridgway Dynamo and Engine Company, Ridgway, Penn.—Bulletin 31 describes the construction and gives the advantages claimed in the operation of Ridgway turbo-generator sets.

Pittsburgh Transformer Company, Pittsburgh, Pa.—Bulletin 2033 describes the Pittsburgh distributing transformer, single-phase and polyphase. Bulletin 2030, describes the copper alloy steel tanks for Pittsburgh transformers. Bulletin 2031 describes the Pittsburgh expansion-tank type transformer.

American High-Speed Chain Company, Indianapolis,. Ind.—Announcement is made and dimensions are given of standard stock sizes of chains and sprockets in several ratings ranging from 2 to 10 hp. with reductions of 3-, 4-, 4½- and 5-to-1, which are carried in stock.

General Electric Company, Schenectady, N. Y.—Circular 66022 entitled, "Outdoor Current and Potential Transformers," gives the characteristics and operating conditions as well as dimensions of this equipment for circuits up to 15,000 volts.

The Northern Blower Company, West Sixty-fifth Street and Wheeling and Lake Erie Railway, Cleveland, Ohio—Bulletins describe the line of direct motor driven exhaust fans, air filters and metal insulated ovens for core baking, mold drying and japanning.

Condit Electrical Manufacturing Company, South Boston, Mass.—A folder describes the Type N-4, oil motor starter for motors of 5 hp. or less on 600 volts or less.

H. Kleinhans Company, Pittsburgh, Pa.—A folder describes the "Uni-flo" welding wire, the different grades, sizes and composition and the purposes for which each is best adapted.

Buffalo Forge Company, Buffalo, N. Y.—Catalog 465 covers the line of unit heaters and their installation in various industrial plants. These heaters are easily installed.

Reminiscences of a Trouble Shooter

(Continued from page 184)

can be very greatly simplified by coating a portion of the commutator with shellac and applying very finely sifted sand. Rotate the machine slowly until a fit is assured. Then clean the commutator with alcohol. When using a stone of any kind on a commutator, I consider it to be the best practice, wherever possible, to shut down the machine and remove the brushes. Otherwise, the small particles tearing from the stone will cling to the commutator and destroy the life of the brushes by wear and giving them a coarse fit on the commutator when the operation is completed, with resultant dirt and blackening.

"If at any time it should be necessary to turn a commutator, great care must be taken to prevent chips from lodging in the risers. To prevent this, obtain a piece of muslin of sufficient length to go around the commutator and wide enough to extend a couple of inches beyond the risers. Lay this piece around the commutator and tie it as close to the risers as possible. Then lift the cloth off the commutator and over the risers and tie it in place over the top of the riser connections on the armature.

"Pete," said Ed at this point, "I wish you would warn your readers that in the application of any of the things I have told you, it will be up to the operator to use his best judgment as to whether or not they will be practicable for his application. I have found them beneficial in some instances, while in others they would not be applicable at all.

"Likewise, the solutions of troubles related apply to actual instances, but this is not *prima facie* evidence that they will solve every trouble. The point that I would like to emphasize is that a trouble may be more mechanical than is anticipated and more simple than it appears. Likewise, it may be a combination of the two arising simultaneously and, on the other hand, an apparent trouble of a mechanical nature with electrical trouble arising therefrom.

"In this connection, it was but a short time ago that I 'cut in' two turbo-generators with exciters attached. The switchboard was installed by a local firm and was giving trouble and to assist their man in testing his board I was running one of the turbos idle with 90 volts on the exciter. There was a momentary groan and all of his meters read backwards, which indicated a reversed exciter, yet only one of the exciters was in service. As it was past quitting time, we shut down for the night and on starting up the following morning the exciter could not be built up. Completely neutralized, it was. But after being re-excited from the other exciter it gave no further trouble.

"What had evidently happened was that the switchboard man had in some way completed the alternator field and immediately broken it, with the result that it discharged through the exciter and reversed it. This is an example of a very simple trouble that is known to exist and can and will cause an electrical trouble where no trouble existed previously. To get at the root of any trouble, obtain a thorough understanding of the mechanical and electrical principles involved in the operation of the equipment, and from this point work outward to your trouble. Leave the design and the engineering principles to the manufacturer."